PB-234 606

PROCEEDINGS NATIONAL SYMPOSIUM ON FOOD PROCESSING WASTES (4TH) HELD IN SYRACUSE, NEW YORK ON MARCH 26-28, 1973

Pacific Northwest Environmental Research Laboratory

Prepared for:

Cornell University
National Canners Association

December 1973

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PB 234 606

SELECTED WATER RESOURCES ABSTRACTS
INPUT TRANSACTION FORM

1. Report No.

2.

3. Accession No.

W

5. Report Date

6.

8. Performing Organization Report No.

PROCEEDINGS FOURTH NATIONAL SYMPOSIUM ON FOOD PROCESSING WASTES

Pacific Northwest Environmental Research Laboratory, National Canners Association and Cornell University

10. Project No.

9. Organization
Industrial Wastes Branch
Pacific Northwest Environmental Research Laboratory
Environmental Protection Agency, Corvallis, OR 97330

11. Contract/Grant No.

13. Type of Report and Period Covered

12. Sponsoring Organization

Environmental Protection Agency report number EPA-660/2-73-031
December 1973

The Proceedings contains copies of 25 of the 27 papers presented at the Symposium. Subjects included: waste characterization, product and by-product recovery, process modification, and wastewater treatment of many different segments of the food processing industry.

The two and one-half day symposium was attended by approximately 225 members of industry, universities, consulting firms and state and federal agencies. Typical papers include: biological treatment of winery stillage, meat packing wastewater, potato processing wastes, dairy wastewaters, distillery wastes and egg processing wastewaters; process modifications for blanching vegetables; as well as by-product recovery from fish processing effluents, cheese whey and sauerkraut wastewaters.

*Industrial Wastes, *Food Processing Industry, *Treatment, By products

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EPA-660/2-73-031
December 1973

PROCEEDINGS FOURTH NATIONAL SYMPOSIUM ON FOOD PROCESSING WASTES

March 26-28, 1973
Syracuse, New York

NATIONAL WASTE TREATMENT RESEARCH PROGRAM
Pacific Northwest Environmental Research Laboratory
Environmental Protection Agency
Corvallis, Oregon

Program Element #1BB037

Prepared for
NATIONAL ENVIRONMENTAL RESEARCH CENTER
OFFICE OF RESEARCH & DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
CORVALLIS, OREGON 97330

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FOREWORD

This Fourth National Symposium on Food Waste Treatment Research was again co-sponsored with the National Canners Association and this year was a joint meeting with Cornell University and its Fifth Agricultural Waste Management Conference. The fine meeting arrangements made by Ray Loehr and his associates and the assistance in finalizing the technical program are gratefully acknowledged.

The purpose of this Symposium was to present current research and development data on the treatment of food processing wastes to those directly concerned with their application. Those of us in the federal research program are convinced that there is no substitute for direct personal contact between researchers and industry and government representatives if we are to achieve a rapid transfer of research findings into hardware.

We note a shift in research goals. We have been concerned in the past with the refinement of treatment methods in order to obtain ever higher degrees of removal of pollutants from waste streams. The 1972 Amendments to the Water Pollution Control Act, declaring a 1985 goal of zero discharge of pollutants, now dictates that we can no longer be content with demonstrating waste treatment removals of 85, 90, 95, or 98 percent. We must now look to complete closed loop water systems. We will not accomplish this by treatment alone.

Instead, we must change in-plant processing methods to reduce or eliminate waste discharges. We must discover useful by-products in these waste streams to help offset treatment costs.

The program for this Symposium indicates we are already re-directing our efforts along these lines. New blanching methods and dry peeling methods are good examples of changes to reduce water use and waste discharges. With continued cooperation such as this between industry and government, we will develop the necessary technology to restore and protect our water environment.

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GOVERNMENT POLICIES RELATING TO WATER POLLUTION CONTROL

by Carroll G. Wills*

I am very happy for the opportunity to be here today and discuss with you government policies relating to water pollution control. Mr. Stein sends his regrets and apologies for not being able to attend the conference but demanding responsibilities required his presence elsewhere.

Before getting into a detailed consideration on Water Pollution Control Policies of the Environmental Protection Agency I think it would be beneficial to briefly cover the evolution of water pollution control legislation. To appreciate the significance of current policies, it is necessary to recognize the weaknesses of the previous Federal pollution control regulatory system.

The first permanent legislation dealing with water pollution was the Water Pollution Control Act of 1948. It provided for the preparation of comprehensive plans to abate pollution. Federal financial assistance was to be provided to the States and municipalities to construct appropriate treatment works. Under the Act the States retained primary responsibility for pollution control. From a jurisdictional standpoint interstate waters were covered. The Surgeon General was the enforcer of the Act and it was necessary to show an endangerment to health or welfare of persons in a state other than the state where the discharge originated. Enforcement of the Act was through a very complex and time consuming administrative procedure which required notices, State consent, the appointment of a hearing Board, and other administrative steps.

In 1956, additional amendments were passed upon the recommendations of the Secretary of Health, Education, and Welfare to streamline the administrative procedure and also alleviate the necessity for State consent which essentially had permitted the States to veto Federal action. Congress complied and passed the 1956 Act. However, this Act simply introduced more delay and added an intermediate procedure. The Surgeon General, if he found actual pollution to exist or if he was petitioned by a State to initiate action, he was required to call a conference. At the conclusion of the conference, if effective abatement action was not taken, the Surgeon General then recommedned that the State undertake action within a reasonable time. If the State did not take action a hearing was then called before a Board. The Board findings and recommendations were then transmitted to the discharger giving them at least six months to comply. If no action resulted, the Secretary could then request the Attorney General to file abatement action. Only one court action was brought under the 1956 Act.

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* Enforcement Specialist National Field Investigations Center - Denver

In 1961 the scope of the Act was broadened to include almost all waters of the nation. Jurisdiction was expanded to include "pollution of interstate or navigable waters in or adjacent to any State which endangers the health and welfare of any persons." Navigable waters were not defined in the Act, but a definite meaning was applied utilizing the Daniel Ball case of 1871; "Navigable, when used or are susceptible of being used in their ordinary condition as highways for commerce."

The Act was again amended in 1965 and provided for the establishment of water quality standards applicable to interstate waters with implementation plans intended to set abatement requirements for each polluter based on receiving water needs. The States again had the primary responsibility to establish standards. If the State did not adopt standards within the prescribed time frame, the Federal Government would call a conference and set standards for the State. Under the 1965 Act, discharges would be subject to abatement if they reduced the quality of interstate waters below the requisite standards. One Hundred Eighty-Day Notice procedures were available as were enforcement conferences when substantial economic endangerment results from the inability to market shellfish or shellfish production in the interstate commerce. The chief defects in the water quality stantards effort were that the requirements were vague and not effectively enforced.

The Clean Water Restoration Act of 1966 provided several additions to the enforcement provisions of the FWPCA. The conference procedure was expanded to include pollution affecting a foreign country and also authorized the Government to require alleged polluters to file reports identifying their discharge.

The Water Quality Improvement Act of 1970 added amendments dealing with water pollution caused by oil spillage including fine and imprisonment for failure to report any known discharge.

Despite the long history of repeated innovations, however, an effective national regulatory system has never been achieved. Anyone working with this system, whether in government, industry or as a private citizen, is aware of its uncertainties, its unpredictable manner of application and its irregular results.

On October 18, 1972, the most comprehensive program ever enacted to clean up the nation's waters became law. Known as the Federal Water Pollution Control Act Amendements of 1972, the new law mandates a sweeping Federal/State campaign to prevent, reduce, and eliminate water pollution. This Bill was the result of long deliberation and great controversy and represents a fundamentally new approach toward our water pollution problem. This legislation abandoned the stream-by-stream system of pollutant accounting and establishes uniform national standards whereby pollutants will be controlled at the source. Precise, detailed abatement requirements will be established. They will be enforced through streamlined legal procedures and heavy penalties for violations. These changes will undoubtedly revolutionize the social structure of water pollution control.

The law provides two general goals: 1) to achieve wherever possible by 1983, a goal of water quality for swimming and other recreational uses and clean enough for the production and propagation of fish, shellfish and wildlife; 2) the elimination of discharges of pollutants into all waters by 1985.

While the States retain primary responsibility to prevent, reduce and eliminate water pollution, they must now do so within the framework of a new national program.

For the first time, the law extends the Federal pollution control program to all United States waters; previously only interstate waters were covered by Federal legislation.

Title I of the new Act concerns research and related programs. The EPA is authorized to develop comprehensive programs for water pollution control and to share in the cost of State River Basin Planning Agency operations. Comprehensive programs for research, development, investigations, training and information gathering on a variety of needs related to water pollution control are also authorized. Federal funds are available for these programs.

Title II of the Act authorizes grants to public agencies for the construction of waste treatment works. The Federal share of the total project cost of the construction of publicly owned treatment works is 75 percent. Limitations and conditions do exist, however, under the grant program. For example, States must have area-wide waste treatment management plans, the applicants must adopt a system of user charges that will insure that each user of a treatment system will pay its fair share of the operation and maintenance costs. In addition, industrial users are required to pay an additional user charge that reflects their share of the Federal share of the original capital cost of the project. Funds were authorized, not to exceed $18 billion up through the Fiscal Year ending June 30, 1975. Five billion was appropriated for Fiscal Year 1973. However, this was trimmed by the President to $2 billion.

Under Title III the Law establishes deadlines for actions to control water pollution from industrial sources. Industries discharging into the nation's waters must apply "best practicable control technology currently available" by July 1, 1977, and the "best available technology economically achievable" by July 1, 1983.

EPA is charged by law to issue guidelines for these levels of treatment which will take a number of factors into account. Legislative history of the law indicates that in defining "best practicable" the Congress expects the EPA to consider the cost of pollution control, the age of the facility, the process used, and the economic impact.

Although EPA is to issue guidelines to define "best practicable," I feel confident that within your industrial category the average of the best performers in the food processing waste category is already well established. The question here is one of philosophy, do we move forward with what we know as the overall degree of treatment that will be required or do we time consumingly argue over specific parameters and numbers. I feel the former should be our course of action as the deadlines provided by the law are firm and clear.

By May 1974 new sources of industrial pollution must use "best available demonstrated control technology." This will be defined by EPA in the form of "standards of performance for various industries." Where practicable, EPA may require no discharge at all of pollutants from new industrial facilities.

The discharge of toxic pollutants will be controlled by effluent standards established by EPA. If necessary, a total prohibition of certain toxic pollutants may be required.

For industries who discharge waste into a municipal treatment plant, pretreatment standards will be applied to ensure that the industrial pollutants do not interfere with the operation of the plant or pass through the plant without adequate treatment.

Small business loans are available for firms who would be likely to suffer financial economic injury unless they receive financial assistance to comply with the law.

As far as municipal discharges are concerned, effluent limitations will be established based upon "secondary treatment" as defined by the Administrator. This level of treatment must be met by July 1, 1977. By July 1, 1983, all publicly owned waste treatment plants will have to use "best practicable" treatment.

As stated earlier, Federal aid is available to local governments to assist them in building needed sewage treatment facilities.

In some cases, effluent limitations more stringent than those previously identified may be required in order to achieve water quality standards. There must, however, be a reasonable relationship between the benefits to be derived and the costs of achieving them. Water quality related effluent limitations must be established, however, through a public hearing mechanism.

Under the new Law the framework of State water quality standards provided for under previous amendments has been retained. These were related to interstate water quality standards. The States must, however, also establish water quality standards related to intrastate waters.

Title IV of the 1972 amendments establishes a new system of permits for discharges into the nation's waters. This National Pollutant Discharge Elimination System (NPDES) replaces the 1899 Refuse Act Permit Program. No discharge of any pollutant from a point source is permitted without a permit. This includes municipal treatment plants as well as industrial dischargers.

Permits will be conditioned to meet the requirements and guidelines promulgated by the EPA. These will be specific numerical requirements setting precise upper limits on the waste loads that a plant will be permitted to discharge into our waterways. In the past, a chief weakness of the regulatory programs was the absence of specific yardsticks to measure satisfactory performance. By ending the total reliance on receiving water conditions, the new standards immeasureably simplify problems of determining compliance.

In addition to effluent limitations, permits will also contain compliance schedules. Once issued, the permit will contain in a single document the complete schedule of requirements for each individual plant. Violation of any conditions of a permit issued by the EPA or by a State are subject to the enforcement provisions of the law.

Individual industrial users of municipal waste treatment plants will not be required to obtain a permit. However, each municipal plant permit must identify all industrial users and the pretreatment standards applicable to each industrial user.

The new Act clearly contemplates that the States will assume the primary responsibility for operating the permit program. EPA has issued guidelines identifying an adequate State program. A number of States requested interim permit granting authority prior to full scale approval of their total permit program.

After a State program goes into effect, EPA retains the right to review proposed permits to determine if they meet the requirements of the law. A state's permit program is subject to revocation by EPA after a public hearing if the State fails to implement the law adequately.

In cases where EPA issues permits, State certification is required to assure that the discharge complies with the applicable requirements of the Act and any applicable State requirements.

The public hearing mechanism is available both at the State certification level and to evaluate permit conditions in anticipation of final permit issuance.

The Act established civil and criminal penalties for violations of the requirements of the Act and authorizes the EPA to bring an action against alleged violators. Generally, EPA is required to give notice of any proposed enforcement action to the alleged violator and to the State in which the violation occurred. Direct Federal enforcement would generally be reserved for cases in which the alleged violator fails to correct his violation voluntarily or the cognizant State fails to act.

Title V of the Act includes a number of administrative requirements as well as additional enforcement tools. Under the Emergency Powers provision the Administrator may seek injuctive relief to restrain any discharge that presents an "imminent and substantial endangerment to the health of persons or welfare where such endangerment is to the livelihood of such persons such as inability to market shellfish."

Citizen suits are also available against any person who is in violation of an effluent limitation or an order issued by the EPA. Citizens may also bring an action against the Administrator where there is alleged a failure to perform an act or duty under the Act which is not discretionary.

Legislative history indicates that citizen is defined as "A person or persons having an interest which is or may be adversely affected." Sierra Club v. Morton is cited; non-economic injury to an environmental interest is sufficient. The alleged injury may reflect aesthetic, conservational, and recreational as well as economic values.

The Attorney General is authorized to represent the EPA in litigation unless he fails to take appropriate action within a reasonable length of time. In that event EPA may be represented by its own attorneys.

A savings provision preserves all suits, actions, or other proceedings lawfully commenced under the old Federal Water Pollution Control Act or other laws prior to the passage of the new amendments, e.g., Refuse Act.

This brief summary hopefully highlights the important points of the 1972 amendments and identifies Federal policies with respect to water pollution control. EPA has been making organizational evaluations in order that the requirements of the Act may be carried out as efficiently as possible. The Regional concept which was adopted by EPA at its birth will continue.

In closing, I would like to emphasize that Congress placed strong emphasis on the importance of public participation to prevent, reduce and eliminate water pollution through the mechanism of the 1972 Amendments. The Law directs EPA and the States to provide for, encourage and assist public participation in developing, revising and enforcing all regulations, standards, effluent limits, plans and programs under the Act.

EPA welcomes this directive and looks forward to public participation, for a concerned and involved public is essential to the success of our Nation's efforts to clean up its waters.

BIOLOGICAL TREATMENT OF
WINERY STILLAGE

by

E. D. Schroeder, D. J. Reardon,
R. Matteoli and W. H. Hovey

Department of Civil Engineering - University of California, Davis

INTRODUCTION

Wine stillage (also known as still slops or still bottoms) is the non volatile fraction of the material used for the distillation of brandy and the fortifying spirits needed for sweet wine production. This waste is the primary environmental problem of the California Wine Industry, partially because of the seasonal nature of winery operation and partially because of the characteristics of stillage. California winery operation is concentrated in the short period from late August to early November each year. Some distillation occurs intermittantly during the rest of the year, but the quantity of stillage produced is relatively small. Thus most of the waste is generated, and must be treated during a 45 to 75 day period. Quantities of stillage produced vary with the size of the Winery. The Gallo Winery in Fresno produces up to 600,000 gallon/day.

Fermentation residues are the major source of distilling material during the processing season. The first fermentation process produces pomace material such as settleable skins, seeds and pulp, and the second fermentation process produces Lees, which are yeast and solids coagulated with bentonite and settled. When pomace or lees materials are used in distillation process the waste is called pomace or lees stillage respectively.

Stillage characteristics vary considerably with the source of the distilling material (lees, pomace of wine), the operation of the winery and the type of still used. A general characterization would be that stillage is very high in COD, BOD, suspended solids and acidity however. Typical values reported pomace stillage are given in Table I.

TABLE I

POMACE STILLAGE CHARACTERISTICS [1,2,3,4]

pH	3.5 - 5.0
Acidity, mg/L as $CaCO_3$	1,200 - 3,800
Total Solids, mg/L	13,000 - 30,000
Suspended Solids, mg/L	14,000 - 18,000
Volatile Solids, mg/L	10,000 - 27,000
Total BOD_5, mg/L	2,400 - 17,840

TABLE I (continued)

Total COD, mg/L	34,000 - 53,000
Total Nitrogen, mg/L as N	150 - 330
NH_3 - N mg/L as N	2 4
Total Phosphorous, mg/L as P	1,211 - 1,310
Temperature	150°F

Several significant design and operational problems can be forseen from waste characteristics discussed up to this point. The high organic concentrations restrict the process choice to anaerobic systems or aerobic systems with a high oxygen transfer rate (in terms of mass/time), and the extremely high suspended solids concentrations make satisfactory solids removal by conventionally used techniques very difficult. Acidity and pH values associated with stillage force the use of some form of pH control in the treatment process. Nearly all of the nitrogen in the waste is in the organic form and therefore is available for use in a treatment process only as fast as the organic nitrogen containing compounds are broken down. In addition the total nitrogen in the wastewater falls far short of that needed in aerobic biological treatment process. Finally the seasonal nature of current distillation operations requires that a treatment system have a very short start up time.

Chadwick[3] and Reardon[4] reported on settling experiments with stillage. They found that maximum settling velocities were of the order of 0.28 ft/m (50 gallon/ft^2/day) and that thickened sludge concentrations were only two to three times the original suspended solids concentrations. Addition of coagulant aids (with pH adjustment) did not improve settling rates. Aids used included alum, ferric chloride, and anionic, non-ionic and cationic polymers.

Cell production in biological treatment presents another operational problem. Concentration of cells in the reaction vessel can be estimated by Equation (1)

$$X = Y\,(C_i - C)\,\frac{\theta_C}{\theta_H} \qquad (1)$$

where X is the cell concentration, C is the organic concentration, Y is the cell yield and θ_C and θ_H are the cell and hydraulic residence times respectively. Although high cell concentrations provide high reaction rates and are therefore desirable, limitations are imposed by mixing ability, oxygen transfer rates and secondary clarifier design. The ratio θ_C/θ_H has a minimum value of one when there is no recycle of cells. Cell yield is a function of cell residence time and thus the best system for controlling cell concentration is probably a reactor without recycle and with a detention time related to the desired cell yield.

Current methods of stillage treatment include lagooning, anaerobic treatment and intermittent irrigation. Anaerobic treatment has been used in South Africa [6, 7] with wineries which operate most of the year. Systems used are essentially anaerobic contact processes; i. e. the cell and hydraulic residence times are different. Hydraulic residence times are of the order of 7 to 8 days and effluent COD concentrations are of the order of 500 mg/L. No anaerobic processes are being intentionally operated in the California although Pearson et. al.[2] and Chadwick and Schroeder[3] reported on laboratory scale anaerobic treatment studies. A major problem with anaerobic processes is the slow start up rates which restrict their use for treating seasonal wastes.

Lagoons are used by a number of wineries in the San Joaquin Valley. Odor complaints have been a general problem associated with these systems. Unfortunately design loadings associated with the production of odors are not known.

Intermittent irrigation has proven to be the simplest and least expensive method of stillage disposal. Maximum loading rates are 100,000 gallons per acre per week. Operation is on a batch basis. Furrows are filled and period is allowed for evaporation and percolation. Dry solids residue is then removed or disced into the soil and the field can be reused. Nuisance problems with this procedure are not great, particularly if the disposal area is separated from residential or commercial areas. There has been some concern about potential damage to ground water quality from irrigation[10], but information is not available which would allow evaluation of the problem. York has recently reported on studies of soil core samples in fields when intermittent irrigation has been used. His tentative conclusion is that salt transmission is not a significant probelm. Tile drainage would undoubtedly be a solution if a threat to ground water is shown.

Trickling filters[12, 13] and activated sludge processes[14, 15] have been used to some extent for the treatment of stillage, but with little success. Rates of oxygen demand have invariably been larger than the oxygen transfer capacities of trickling filters used. Filamentous growths have been the major probelm in the operation of activated sludge processes.

U.C. DAVIS STILLAGE TREATMENT STUDIES

The University of California at Davis has been involved in the study of stillage disposal methods since the revival of the California wine industry in 1933. Much of the work has been Vaughn and his co-workers[12, 16, 17]. In 1970 studies were initiated by the Environment Engineering Program of the Department of Civil Engineering on the characteristics and treatability of pomace stillage. These studies were with support from the Environmental Protection Agency and the Wine Institute, to include operation of aerobic and anaerobic pilot scale treatment plants at the Gallo Winery in Fresno.

A schematic diagram of the pilot plant system is given in Figure 1. Three systems were studied, anaerobic packed beds, two stage aerobic and a large aerobic unit, equal in volume to the total volume of the two stage units. Laboratory scale studies at Davis were continued using frozen stillage. This latter work consisted of aerobic studies on loading rate effects, anaerobic treatment and solids removal and concentration.

Goals of the research program included development of technically acceptable treatment processes and the estimation of costs associated with each form of treatment proposed.

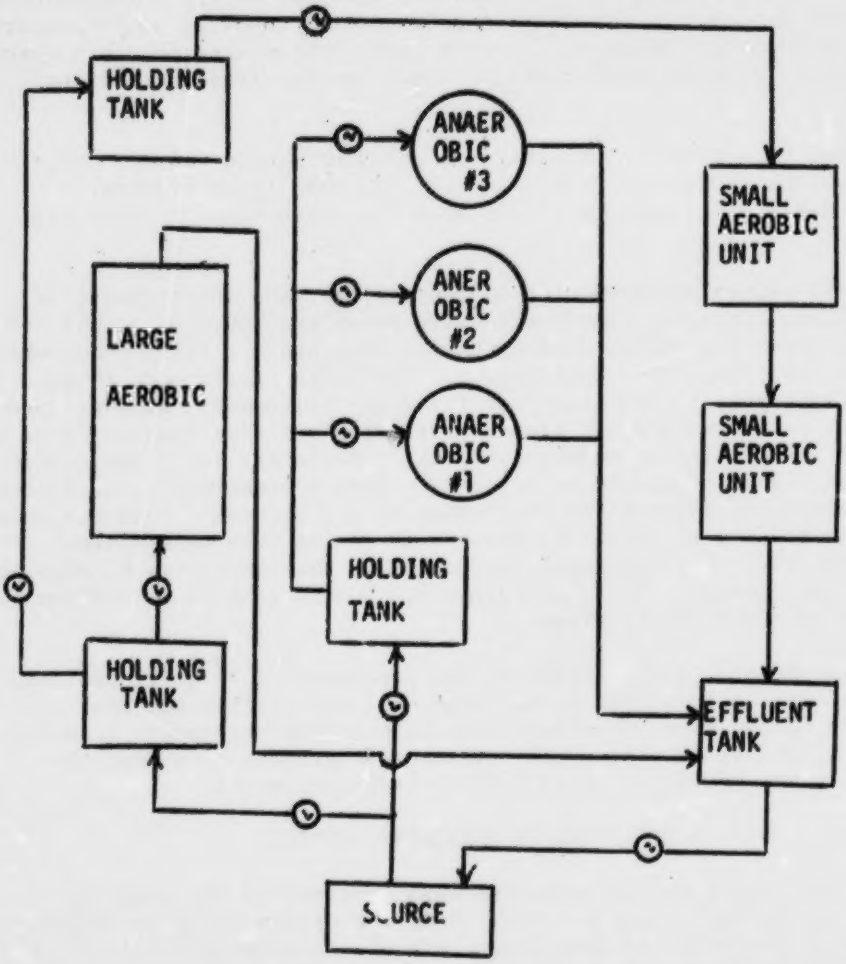
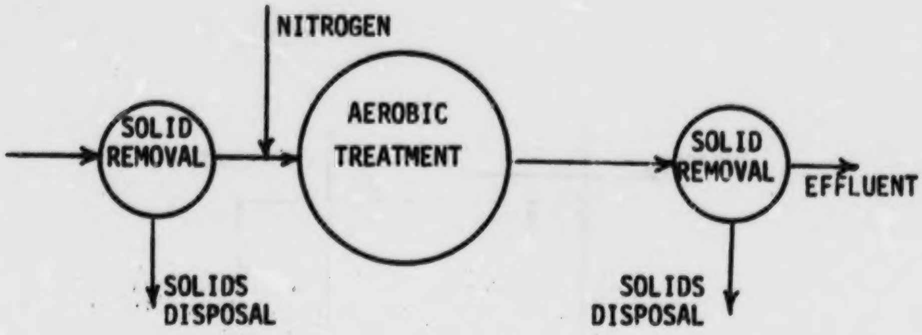

HOLDING TANK
ANAEROBIC #3
ANEROBIC #2
ANAEROBIC #1
SMALL AEROBIC UNIT
SMALL AEROBIC UNIT
LARGE AEROBIC
HOLDING TANK
HOLDING TANK
EFFLUENT TANK
SOURCE

FIGURE 1: PILOT PLANT SCHEMATIC

Pilot Scale Program

Pilot scale treatment units were designed to operate on settled stillage supernatant. Settling tanks used were designed for overflow rates of 50 gallon/ft^2/day at maximum anticipated flow rates. Active volume of the aerobic units was 72 ft^3 and 144 ft^3, respectively (Figure 2). Aeration was by 70 rpm surface aerators with two foot diameter flat bladed turbines. Two aerators were used in the large aerobic unit and one in each smaller unit. Provision for possible cell recycle was made by including attached sedimentation units. Cell recycle was not used and the secondary sedimentation units were by-passed throughout the studies. The systems were started using an activated sludge culture obtained from the city of Malaga treatment plant.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AEROBIC TREATMENT
SOLID REMOVAL
EFFLUENT
SOLIDS DISPOSAL
SOLIDS DISPOSAL

FIGURE 2

TREATMENT SYSTEM USED IN AEROBIC LABORATORY AND PILOT SCALE PROCESSES

The anaerobic packed bed units (Figure 3) were three feet in diameter and eight feet high. Total packed volume was 42.5 ft^3. Packing media was a mixture of 2 inch Douglas fir and redwood bark chips. Provision for influent heating was made in the design, but equipment supply problems prevented installations of the heaters in the packed beds before unit start up. Heaters were added to the sedimentation tank, but temperature control was inadequate throughout the studies. The anaerobic systems were started up in Fall, 1971 using a culture obtained from the City of Fresno digesters. Following the 1971 operating season the anaerobic systems were left undrained in order to determine the need for annual reseeding of the units and the fate of solids accumulated during the processing season.

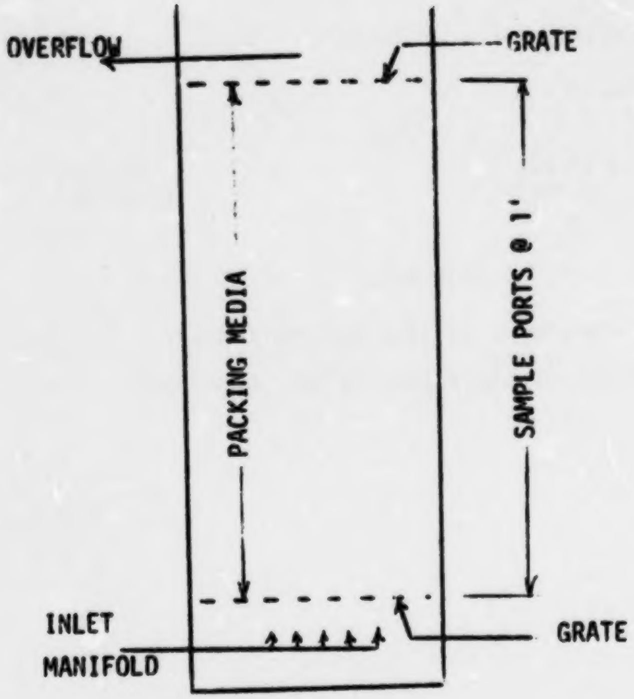

FIGURE 3 ANAEROBIC PACKED BED REACTOR

Loading rates used in the pilot scale studies were based upon data from the laboratory scale studies on pH control. Hydraulic residence time was maintained at three days in both the aerobic and anaerobic systems. Because there was no cell recycle in the aerobic system mean cell residence time was also three days. In the anaerobic systems cell residence time is not equal the hydraulic residence time and because of the suspended solids include both cells and stillage solids an adequate method of estimating mean cell residence time is not available. Volumetric organic loading rates were approximately 0.4 lb/ft^3-day for both aerobic and anaerobic systems. Nutrients were not added because of the excessive amounts that are necessary stoichiometrically. Using a 20:1 COD to N ratio the amount of nitrogen needed in an aerobic stillage treatment system is approximately 1000 mg/L. Assuming nitrogen present in stillage is available to the bacteria means that addition of 850 mgN/L is necessary . This corresponds to 3230 mg/L of ammonium chloride or 2130 mg/L of ammonium nitrate. For Gall-Fresno this would correspond to over 9,000 lb of ammonium nitrate per day. Laboratory data reported here is from systems with nutrients supplied, and the two sets of data (pilot and laboratory) together provide information on prototype system design.

Laboratory Scale Program

Three groups of laboratory experiments were run: Two stage aerobic biological treatment processes, CFSTR anaerobic biological treatment processes and physical-chemical treatment for solids removal. The latter group of experiments resulted from early experience with stillage treatment which led to the conclusion that a method of concentrating solids would be necessary. These studies are not completed and will not be discussed here. All of the experiments used stillage obtained at the Gallo Winery-Fresno. The stillage was transported to Davis and frozen at -30°C until used.

A complete report on the two tanks in series aerobic treatment process is given by Rearden[4]. Two identical, completely mixed, laboratory scale activated sludge units were placed in series. Settled (24 hr) stillage without pH adjustment, but with excess nitrogen (3.6 gr/L NH_4Cl) added, was fed to the units at selected flow rates. Hydraulic, and therefore mean cell, residence times used ranged from 4.7 days down to 1.1 days. The systems were monitored until steady state conditions were achieved. Under the conditions imposed on the treatment units pH was an excellent indicator of process performance. The low pH and high acidity of stillage was due, primarily, to organic acids. As long as the organic acid conversion rate equals the input rate pH remains near neutral. When input rate exceeds the removal rate effluent COD concentrations increase and pH values decrease because of the unconverted organic acids present.

The anaerobic treatment units had a volume of 1.5 liters and were operated in an incubator at a temperature of 110°F. Three residence times were used, 15 days, 30 days and 60 days. All of the units were fed once a day and thus were operated on a batch basis. Stillage COD used in the anaerobic experiments was 15,500 mg/L. Nitrogen was added to the feed as NH_4Cl.

EXPERIMENTAL RESULTS

Laboratory Scale Experiments

Results of the anaerobic experiments were not promising. The 15 day residence time unit failed completely, producing very little gas and having a COD of about 14,000 mg/L. At a 30 day residence time COD concentrations were reduced to an average value over a two month period of 5100 mg/L with a gas production of 500 ml/day and a pH of 6.9. The gas production corresponds to 15 ft^3 of gas per pound of COD removed. Operation at a residence time of 60 days did not improve COD conversion measurably, and of course gas production decreased proportionately.

Aerobic treatment studies used settled stillage as a feed. Settling properties of raw stillage vary from sample to sample, but are uniformly poor. Results of typical settling tests on aerobic unit sludge or on raw stillage are shown in Figure 4. Settling rates varied from about 6 ft/day (45 gallon/ft^2-day) down to zero ft/day (no interface formed and very little solids accumulation occurred on the cylinder bottom over a 24 hr period). The aerobic biological treatment studies were run with a stillage which settled reasonably well, having a supernatant liquor with suspended solids and COD concentrations of about 1200 mg/L and 19,000 mg/L respectively after a 24 hour settling period. Influent characteristics were constant for each experiment (i.e. each residence time), but varied somewhat throughout the study (Figure 5).

The aerobic reactors used had a 3.5 liter volume and were aerated by diffusers. Feed was pumped into the units using a peristaltis pump which was activated by a cam timer operating on a 20 min cycle. Temperature was maintained at 23°C by housing the system in a walk-in incubator. All date reported was taken over a fourteen day steady state operating period at each residence time.

Total reactor suspended solids concentrations are given in Table II.

TABLE II

MIXED LIQUOR SUSPENDED SOLIDS CONCENTRATIONS, mg/L

θ; days	Reactor 1	Reactor 2
1.09	5600	7400
1.41	8400	6800
1.87	8700	6700
2.42	9200	6900
2.75	8700	6900
3.58	7100	5900
4.67	7200	6100

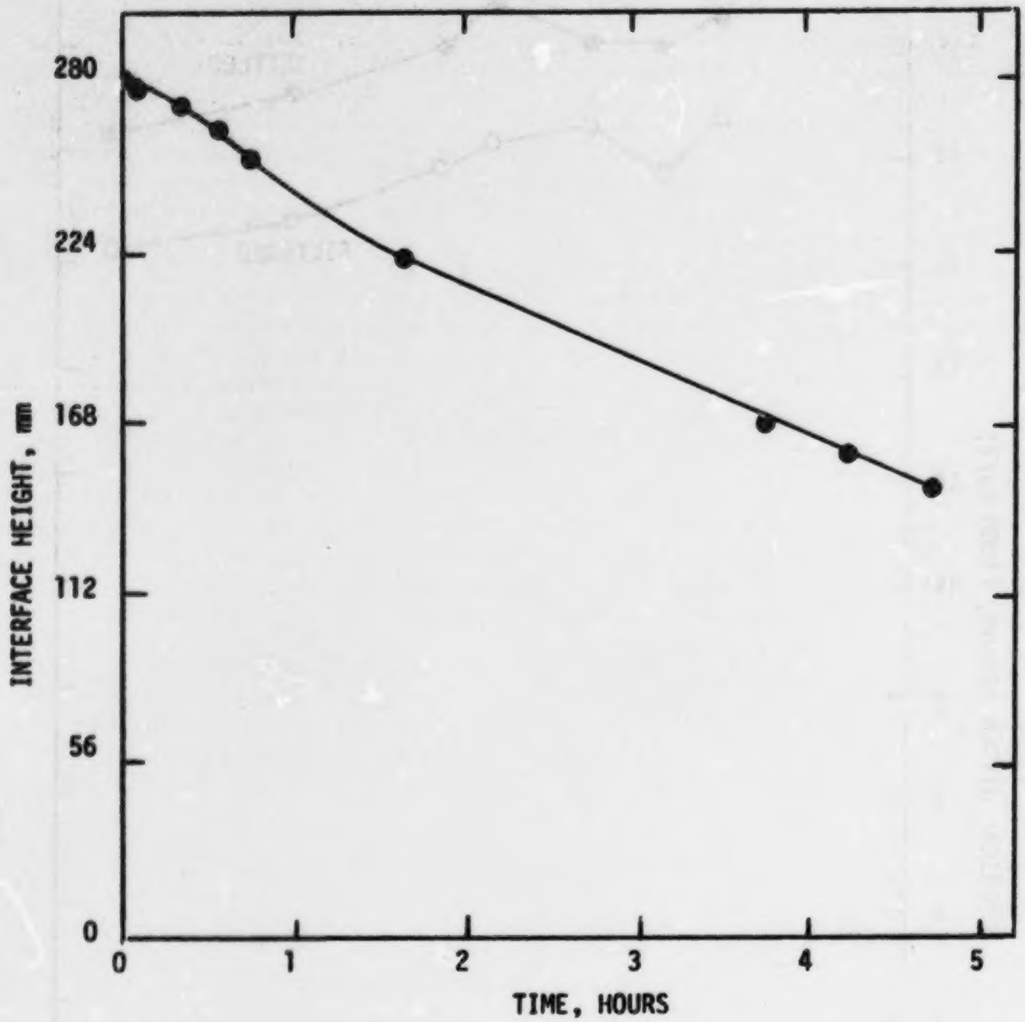

FIGURE 4 TYPICAL RAW STILLAGE SETTLING CURVE

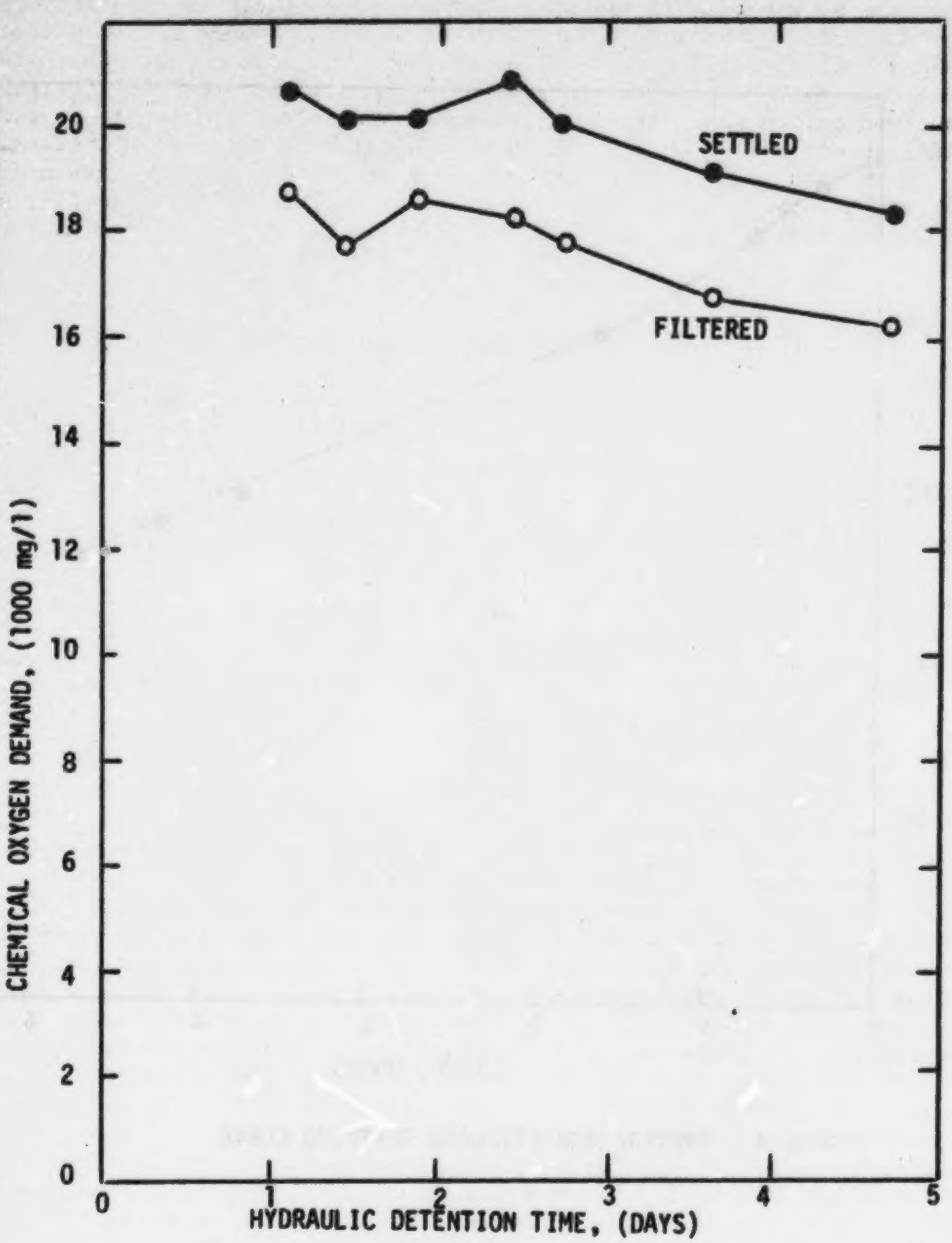

FIGURE 5

STILLAGE FEED CONCENTRATION VERSUS HYDRAULIC DETENTION TIME FOR LABORATORY REACTOR

Effluent quality, as measured by COD concentration was not improved by using the series reactor system. Operation was stable in the first reactor system at residence times down 1.4 days, although sludge settling deteriorated below values of 1.87 days. Settled effluent COD values were somewhat lower in second unit but filtrate COD values were virtually the same for both units. Dissolved oxygen concentrations reflected the relative activity of the two units, as was mentioned previously pH was not controlled, but instead was used as a measure of overloading. Values of pH, dissolved oxygen and effluent COD concentrations are reported for the first reactor in Table III, and Figure 6. Biochemical oxygen demand (BOD_5) of the effluent was approximately 75 mg/L.

TABLE III

OPERATIONAL VARIABLES FOR AEROBIC TREATMENT STUDIES

θ, days	DO mg/L	pH	Effluent COD, mg/L Settled	Filtered
1.09	1.9	5.1	12,079	7,009
1.41	3.1	6.5	2,264	636
1.87	3.2	6.3	1,484	592
2.42	No Data	6.3	3,303	763
2.78	3.7	6.1	2,380	643
3.58	5.2	6.2	1,484	537
4.67	6.6	6.6	---	666

Removal rates, cell growth rates and cell yield are important parameters in process design. Normally the rates are believed to be linear functions of the cell mass concentration and this allows the use of specific or unit rates (rate per unit mass of cells). Because the suspended solids concentration of the settled stillage was high (1200 mg/L) the mixed liquor suspended solids concentration (MLSS) could not be assumed to represent the cell mass concentration, and thus could not be directly used in calculating unit rates. Substracting stillage suspended solids from the MLSS concentration to obtain an estimate of the cell mass concentration can be justified. Stillage solids include grape pulp, bits of stems and leaves and yeast cell residues, all of which have been broken up during the distilling process. Thus the material remaining in non-soluble form can be assumed difficult to degrade. Subtraction of the settled stillage from the MLSS concentration and using this estimated cell mass concentration to calculate the unit removal rate results in the information presented in Figure 7. Unit growth rate in a well mixed unit without cell recycle is equal to the inverse of the hydraulic residence time. The ratio of the two rates (Growth Rate/Removal Rate) is the cell yield, and as noted on Figure 7, the value is 0.37 grams of cells produced per gram of COD removed.

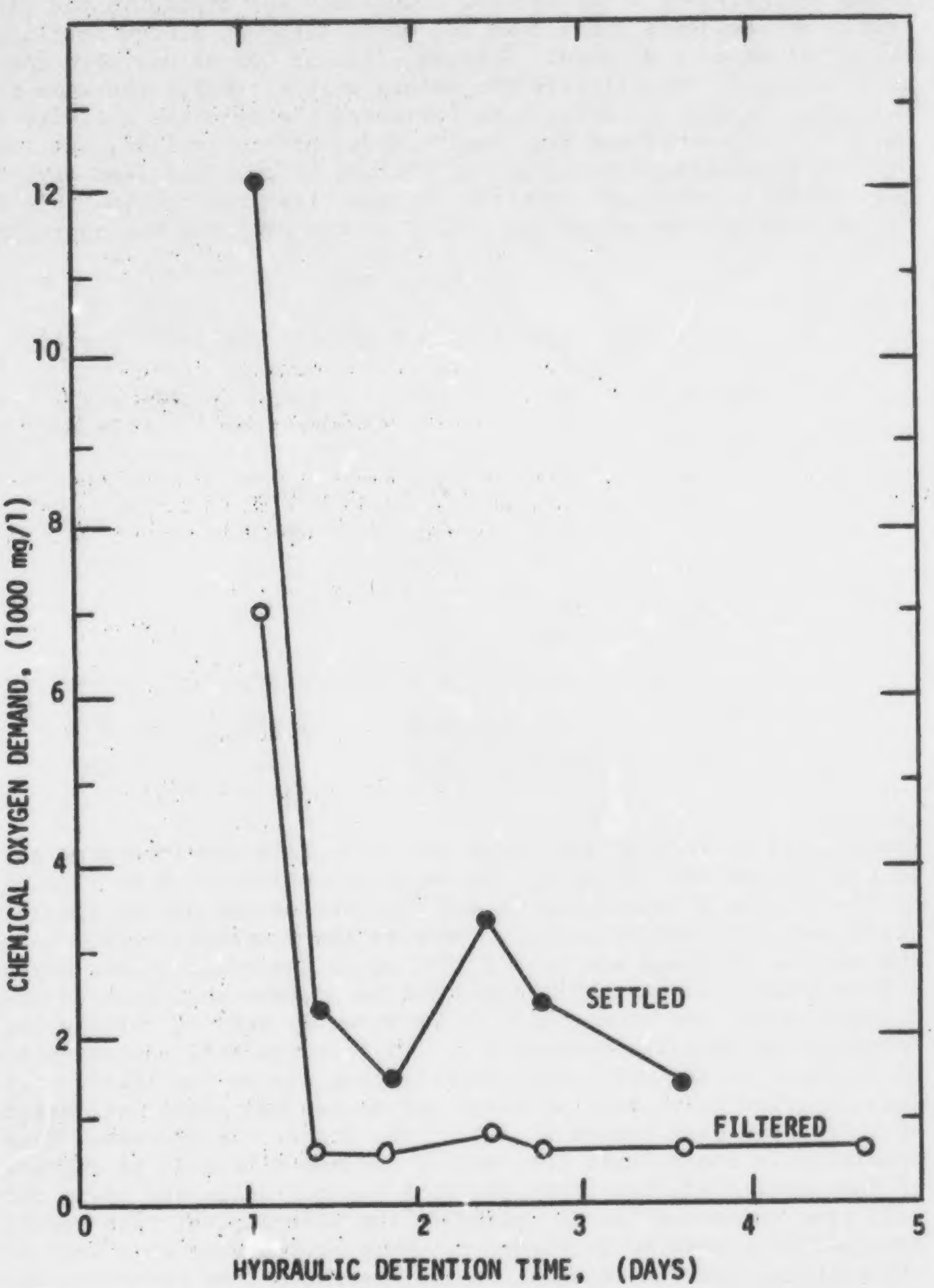

FIGURE 6

EFFLUENT COD CONCENTRATION VERSUS HYDRAULIC DETENTION TIME FOR LABORATORY REACTOR

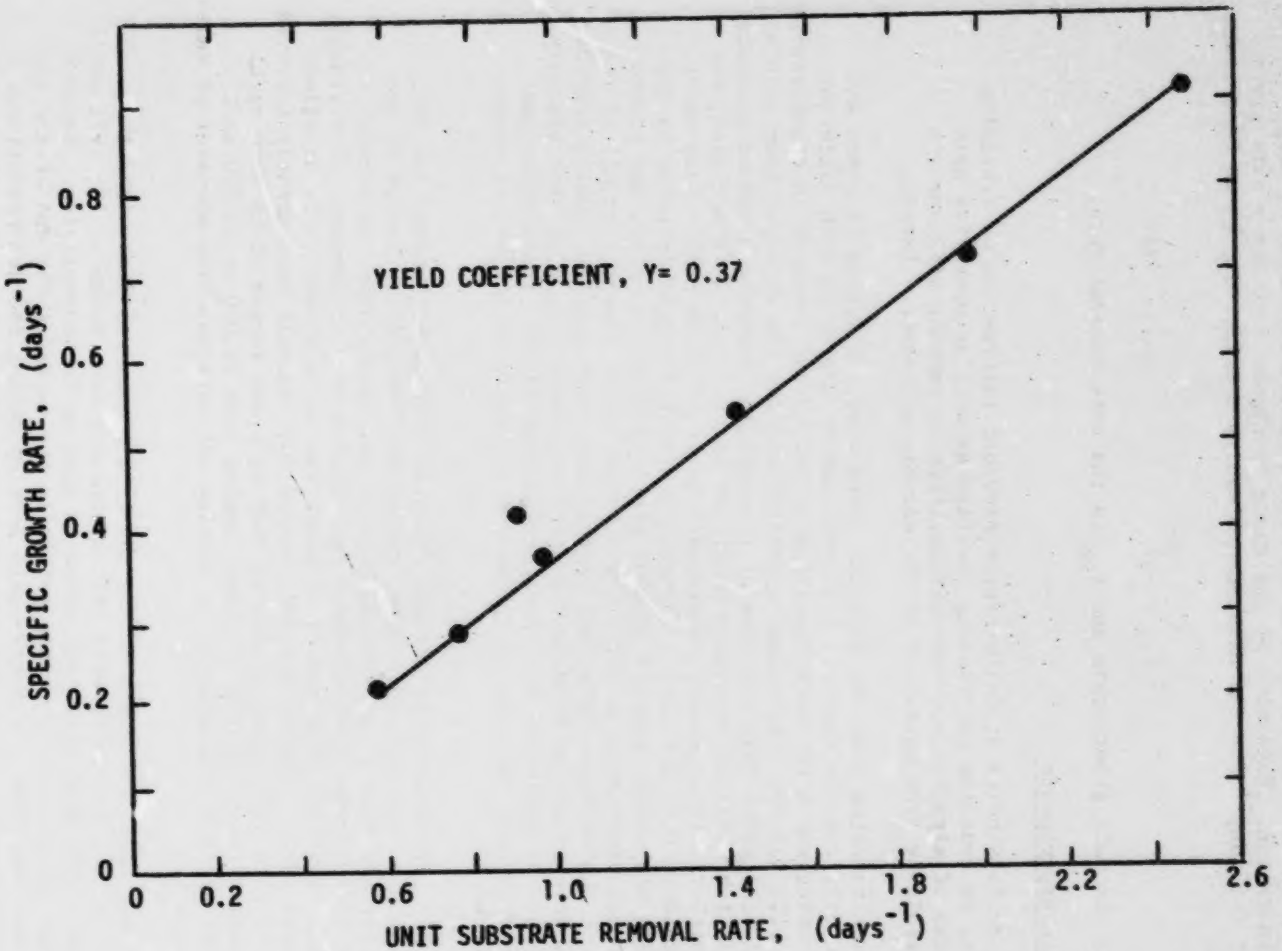

FIGURE 7

SPECIFIC GROWTH RATE VERSUS UNIT SUBSTRATE REMOVAL RATE

Net cell yield is not a constant due to increasing cell maintenance energy requirements with increasing cell age. Estimation of the maintenance energy requirement is difficult with the data presented here because of the high growth rates used in the study and the method of determination of cell mass concentration. Extension of the curve in Figure 7 to the y axis gives a value of 0.01 day^{-1} for the maintenance energy coefficient, k_d in Equation (2) below:

$$\mu = -(Y\, r_{ox} - k_d) \qquad (2)$$

where μ is the unit growth rate and r_{ox} is the unit removal rate.

Pilot Scale Experiments

The pilot scale studies at Gallo-Fresno provided information on operating problems to be expected in treating stillage as well as operating data. Two problems of significance were difficulties in pumping stillage and foaming resulting from agitation in the aerobic processes. Pumping difficulties resulted from the impellar sizes used. Clogging by stems and debris was difficult to control, but would not be a problem with different pumps. Foaming was a far more significant problem and resulted in considerable problems, both for the pilot plant operation and for the winery. Foam layers built up to the point that overflow of the aeration tanks occurred on occasion. In addition the attached secondary clarifier units (which were not used, but through which the flow passed) developed a layer of thick stable foam which often overflowed the tank also. The foam restricted oxygen transfer by the surface aerators which resulted in odor problems from the units, and proved to be an ideal breeding area for flies. Screens were placed over all of the units except the aeration tanks and insecticides were applied. Gallo provided advice and help on the problem, but control was never completely satisfactory. Because of the proximity of the experimental area to the winery there was considerable concern that the fly probelm would cause action by the county health officer.

The anaerobic treatment units did not function well during either the 1971 or 1972 season. Lack of temperature control was the primary factor in the poor results, and thus data reported here is only qualitative in nature. During the 1971 season which extended from September 5 to November 15 virtually no anaerobic treatment took place, although the units proved to be excellent sedimentation tanks. During the 1972 season COD removals were greatly improved. Effluent filtrate COD values as low as 3900 mg/L and ranged up to 7500 mg/L were obtained with influent COD values ranging from 16,000 to 19,000 mg/L. Good control of pH was maintained by cutting off influent flow whenever pH values dropped below 6.5.

Startup of the anaerobic units during the 1972 season was done without adding new cells. The units were left unattended from November 15, 1971 until early August, 1972 when water was added to make up for evaporation. Because of the large quantities of organic solids in the tanks at the end of the 1971 season it was felt that a culture would develop during the non-operational period. Evidently a culture did develop because there were no start up problems and COD conversion was much improved as noted previously.

Aerobic treatment results must be evaluated in light of the lack of available nitrogen. Effluent filtrate COD values ranged from 1460 to 7320 mg/L with an average value of 4600 mg/L. Settled Effluent COD values were about 1800 mg/L greater than filtrate COD values. Suspended solids concentrations in the aeration tank varied with the settleability of the incoming stillage. Values ranged from 7500 mg/L to 14,000 mg/L. Data for 1972 correlated very well with that obtained in 1971.

Significant start up probelms did not occur either year, and pH control was not a probelm as long as the system was not organically overloaded. The major operational problems were stillage solids during periods when stillage settleability was poor, and foaming. Both solids and foaming retard oxygen transfer and thus decrease process efficiency.

Discussion

Biological treatment of California winery stillage is possible, either aerobically or anaerobically. Because of the seasonal nature of the waste, anaerobic processes would seem to be less desirable than aerobic treatment, however. Aerobic treatment of settled stillage can produce effluents with filtrate COD and BOD_5 values of the order of 700 mg/L and 75 mg/L respectively. Settling rates of the activated sludge are very low, even after further aeration in secondary units, and the quantity of non-settleable material is relatively high. Thus while aerobic treatment does an excellent job of converting organic material, the residual effluent COD and suspended solids concentrations are still unsatisfactory. Finally the quantities of nitrogen which must be added are extremely high. Ammonium chloride should not be used because of the high quantity of chlorides which would be added to the effluent. Less ammonium nitrate is needed on a pound per gallon basis, but ammonium nitrate is about twice as expensive as ammonium chloride.

Any successful biological treatment process will be dependent upon pretreatment for solids removal. Successful solids removal will involve concentration to about ten percent. This is necessary to mininize the solids volume to reasonable proportions. Several methods of treating the solids are possible, including anaerobic digestion.

Following solids removal aerated lagoons designed for a three to three and a half day residence time should be used to remove most of the organic material. In order to reduce the nitrogen requirement nitrogen should not be added to these lagoons, but instead should be added to the effluent as it flows into a second set of aerated lagoons. The organic concentration will be about 20 to 25 percent of that in the settled stillage, allowing a correspondingly lower addition of nitrogen. Effluent from the second set of aerated lagoons should be allowed to settle in holding ponds with a minimum of one day residence time. Settled solids can collect on the bottom and degrade during the non-operating months. A schematic of the proposed process is shown in Figure 8. Effluent from the final ponds should be suitable for irrigation or possibly for discharge into municipal sewers.

Foaming problems will be less than those experienced in the pilot studies in larger ponds. Good solids removal will also remove much of the light pulpy material which gave the pilot study foam the properties most difficult to deal with.

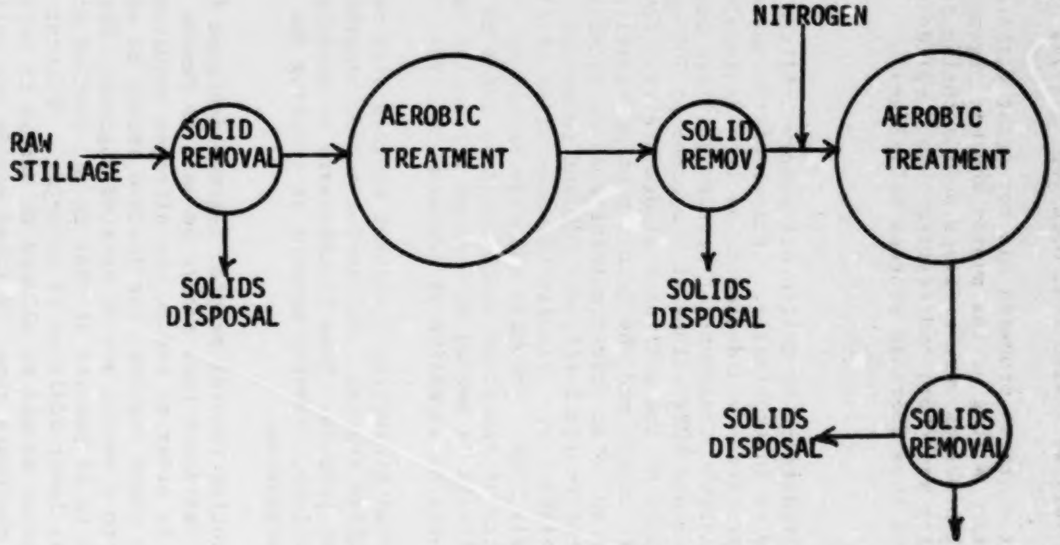
RAW STILLAGE
SOLID REMOVAL
SOLIDS DISPOSAL
AEROBIC TREATMENT
SOLID REMOV.
SOLIDS DISPOSAL
NITROGEN
AEROBIC TREATMENT
SOLIDS REMOVAL
SOLIDS DISPOSAL

FIGURE 8 PROPOSED TREATMENT PROCESS

Biological treatment of winery stillage is an alternative to intermittent irrigation. Prior to any changes in the present method of disposal intermittent irrigation should be studied further. The possible use of tile drainage to collect the wastewater should be considered, together with study of the quantity and quality of water actually moving through the soil. If nuisance problems exist some effort should be made to develop a systematic method of application and of nuisance control.

ACKNOWLEDGMENTS

The financial support and encouragement of the U.S. Environmental Protection Agency, the California Wine Advisory Board and the Wine Institute are greatfully acknowledged. Charles Crawford, Ted Yamada and Bob Slayton of Gallo Wineries gave continuous and enthusiastic support, even in difficult times and this was appreciated greatly. Fresno State College generously provided space in the Enology laboratory to perform analytical work and this also was appreciated.

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RECYCLING SPENT CUCUMBER PICKLING BRINES***

by

R. E. Henne* and J. R. Geisman**

INTRODUCTION

The growing concern of mankind with environmental pollution problems has led to an increasing effort on the part of educational institutions, industry, governments, and society to find ways to reduce, arrest, and roll back the degradation of the environment. The general problems of industrial pollution abatement and that from food processing in particular is receiving the attention of a significant number of qualified scientists.

Sodium chloride (salt) is a significant contributor to the pollution of our environment. Although cucumber processing salt brines contribute a very small part to total saline pollution, the problems they present are important to pickle processors and to communities in which they are located. A solution to the problems confronting Ohio's pickle processors could be applied to the larger problems of industrial salt pollution.

In 1970 the U.S. fermented about 350,000 tons of cucumbers (1). Calculated from pack-out ratios this process produced about 30 million gallons of "spent" brine (1). Ohio's cucumber salting stations produce roughly two million gallons of such brines annually. The salt content of pickle brines ranges between 10 and 18 percent.

The Federal Water Pollution Control Act (1956 - amended 1961, 1965, 1966, 1970), the National Environmental Policy Act (1969), and the administrative regulations promulgated to enforce them (2,3), particularly the Water Quality Surveillance Network and Environmental Protection Agency's (EPA) Construction Grant Regulations, Part 601.34 (c) (4) emphasize the urgent need for a solution to this problem. Most of Ohio's briners discharge their wastes in to domestic sewage treatment systems as do other picklers throughout the U.S. The Construction Grant Regulations force such facilities to surcharge industrial users on a fair-cost recovery basis or lose Federal assistance for construction or improvement

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***Publication approved by the Director Ohio Agricultural Research and Development Center, Wooster as Journal Article No. 33-73.

of their treatment facility. The impact of this provision upon pickle processors who discharge their wastes to municipal treatment facilities becomes apparent when a waste strength of approximately 2,000 ppm of suspended solids and 7,000 to 10,000 ppm Chemical Oxygen Demand (C.O.D.) is considered.

The United States produces more than 30 million tons of salt annually - nearly all of it from practically pure solid deposits laid down millions of years ago by evaporation of ancient seas. The continued use of salt from such deposits can only increase the salt content of the earth's waters. This increase is first apparent in fresh or estuarine waters near the pollution source. It will eventually increase salt content of the seas.

This project was undertaken at the Department of Horticulture, The Ohio State University, and the Ohio Agricultural Research and Development Center to devise methods, equipment, and procedures which would provide a low cost, simple means for recycling "spent" cucumber pickle brines and thereby eliminate them as a source of saline pollution.

Recycling of these brines was selected over other methods for preventing saline pollution because salt is not biodegradable and its removal from water requires a phase change.

The objectives of this work were to produce from spent brines:

1. A recyclable brine.
    a. A brine free of suspended solids.
    b. A brine without objectionable odor.
    c. A brine which does not contain softening enzymes.
2. A brine with an aesthetically pleasing appearance.

REVIEW OF LITERATURE

The literature specifically dealing with the reconditioning and recycling of food processing salt brines is limited (5, 6, 7, 8, 9).

Literature bearing upon the various aspects of the overall problem was reviewed. Only those references which have direct application to this project are cited and are subdivided under the appropriate headings.

Water Treatment

The general problem includes, in addition to the salt, soil carried in with the fruit, cucumber constituents leached from the fruit, and residues from the fermentation organisms present in the spent brine.

Behrman (10) reviewed the processes of water purification chemistry in lay terms and defined the methods as:

a. Plain sedimentation -- where particles are simply allowed to settle out.
b. Coagulation -- which is the process of collecting colloidal particles into larger and heavier aggregates or clumps which will settle out.
c. Filtration -- where particles too large to pass

through the filter pore space are removed.

d. Activated carbon filtration -- the removal of color and soluble organic materials.

Behrman (10) also described a "jar test" where different amounts of aluminum sulfate and alkali were added to a measured amount of turbid water, to determine what amounts and pH were best for a particular turbidity.

The U.S. Government (11, 12, 13) is the acknowledged world authority on the desalination of sea and brackish waters. The publications listed constitute a complete compendium of methods for the production of potable water and water for irrigation and industrial uses. These methods included: vertical tube evaporator distillation, multi-stage flash distillation, a combination of the two, vapor compression, solar evaporation, reverse osmosis, transport depletion, crystallization, and ion exchange. A review of this literature served to support the conclusion that recycling in the liquid state would be the most feasible solution for pickle processors.

Waste Treatment

The literature regarding food processing waste treatment deals predominantly with biological degradation of dissolved and suspended organic solids. The fact that salt is not biodegradable eliminated this method from consideration.

Early researchers in the field of saline waste disposal, Boruf (5) and Taylor (14) concluded that the only practical method for treating such wastes was dilution. Recently, Lowe and Durkee (7) demonstrated a submerged combustion unit coupled with an incinerator which ostensibly reduced organic waste to carbon which remained in the dry salt and gases which were driven off.

Cucumber Brining Practices

For a comprehensive treatment of cucumber brining practices, Etchells *et al*. (15) provided a compendium of almost thirty years of research. Jones, *et al*. (16) and Etchells and Jones (17) reported on chemical and bacteriological changes which occur in brine during cucumber salt brine fermentation. They pointed to the softening phenomenon which is of major concern in any attempt at reconditioning. These softening enzymes were introduced into the brine by microorganisms inhabiting the blossoms, ovaries and fruit of cucumbers (17, 18). Enzymatic softening was not restricted to any geographic region (19) and increasing the salt concentration within the limits of bacterial fermentation did not inhibit enzymatic softening (20). Bell, Etchells, and Jones (21) devised a simple test method for determining if enzymatic softening was taking place in fermentation tanks. Phaff and Joslyn (22) reported two types of pectic enzymes,

> "pectinesterase (pectase) which catalyzes the deesterification of pectin by the removal of the methoxyl groups, and polygalacturonase (pectinase) which catalyzes the glycosidic hydrolysis of pectin or pectic acid."

They went on to describe five general methods for measuring polygalacturonase activity in pectic substances. Bell, Etchells, and Jones (21) found a polygalacturonase enzyme in commercial cucumber fermentation which they considered responsible for the softening in these fermentations. Their research indicated that this polygalacturonase-like material and commercial polygalacturonase (pectinol) reacted similarly to adjustment of pH, temperature, salt, and time of incubation. Research regarding the effect of salt concentration showed that this enzyme had a chemical structure and the general characteristics assigned to proteins (20). Once the source of the enzymatic softening enzyme and its true nature were known, researchers turned their attention to the methods and procedures for inhibting it or eliminating it from commercial fermentations. Early briners had discovered (how they discovered it is shrouded in the mists of antiquity) that placing grape leaves in the brine tanks reduced the incidence of soft pickles. Etchells and his associates (19, 23, 24, 25) undertook a series of experiments with grape leaves and demonstrated the presence of a pectinolytic and cellulolytic enzyme inhibitors in several grape cultivars. In 1961, Porter and Schwartz (26) identified this inhibitory substance as a "tannin or tannin-like material." Building upon this knowledge Etchells and his co-workers (5, 27, 28, 29, 30) were able to extract the inhibitor, locate a more abundant source and demonstrate the ability of this preparation to inhibit enzymatic softening.

Reconditioning and Recycling of Food Processing Salt Brine

Popper et al. (31), Mercer, Maagdenberg, and Ralls (8), and Lowe and Durkee (7) working with olive brines either did not encounter an enzymatic softening problem or they did not consider it in their work. Branfield (6) does not mention this potential problem in his work although he does state that the brine was heated to 96.7°C (206°F) as part of the process.

Mercer, Maagdenberg, and Ralls (8), Popper et al. (31), and Lowe and Durkee (7) demonstrated models to recondition and/or recycle spent food processing salt brines. The problem then becomes one of economics. Popper (9) demonstrated a very economical system. His concept combined a chemically produced precipitate with clarification and filtration. He described the physical system as a long narrow tank with porous walls, which operated at very low pressure to avoid the formation of a dense filter cake.

Filter Aids

Filtration, essentially a batch operation, is dependent upon the "life" of the filter. A filter must be replaced when the suspended solids being removed clog the filter pore space. This "blinding" of the filter may be delayed by the use of filter aids which because of their vast pore-space area and incompressibility prevent the accumulation of a dense filter cake. Diatomacous earth with its ability to "pre-coat" cloth filter material and as a body mix to maintain flow rate offers an available and effective material for accomplishing this objective (32, 33).

EXPERIMENTAL MATERIALS AND METHODS

There have been two phases of this work. One was conducted in the plant chemistry laboratory of the Department of Horticulture, Columbus, Ohio. The second phase was carried out at the H. W. Madison Company, Division of the J. M. Smucker Company in Medina, Ohio.

Laboratory Phase

Spent pickle brine was obtained from the commercial firm. Approximately 200 gallons of brine were used in this phase.

Raw Material Examination:

The raw brines were examined to determine properties for comparison with the reconditioned brines in order to evaluate treatment effectiveness. The characteristics evaluated were as follows:

a. Visual Inspection - to determine color and turbidity.
b. Salt Content - determined with a Matheson salt hydrometer according to standard procedures.
c. pH - determine with the aid of a Beckman pH meter with a glass electrode.
d. Total Acidity - determined by titrating to pH 8.1 with 0.1N sodium hydroxide (NaOH). The ml NaOH required was converted by calculation to percent acid as lactic.
e. Suspended Solids - determined with the aid of vacuum filtration by gravimetric analysis.
f. Total, Volatile and Non-volatile Solids - determined according to standard methods (34).
g. Mineral Content - the ashed residue from total, volatile and non-volatile solids assay were ground with a mortar and pestle. This material was analyzed spectrographically for mineral content as the Plant Analysis Laboratory, Ohio Agricultural Research and Development Center, Wooster, Ohio.
h. Chemical Oxygen Demand (C.O.D.) - determined according to standard procedures (35).
i. Dissolved Oxygen (D.O.) - determined by a modification of the Winkler method (35).
j. Light Transmission - determined with the aid of a Bausch and Lomb Spectronic 20 colorimeter from 375 to 580 nanometers.
k. Spot tests for:
    (1) Protein - determined by the Biuret test (36).
    (2) Carbohydrate - determined by the Molisch test (36).
l. Nitrogen - determined by micro-Kjeldahl technique with the digestion step eliminated (37).

Coagulant Screening Tests:

Chemicals screened as coagulants included:

a. Sodium Carbonate (Na_2CO_3) - the "soda ash" used in many municipal water treatment systems.
b. Agricultural Lime ($CaCO_3$) - this material was given a very cursory examination because of its ready availability and very low cost.
c. Calcium Oxide (CaO) - in some parts of the United States calcium oxide is synonymous with lime.
d. Aluminum Sulfate ($Al_2(SO_4)_3$) - the common "filter alum" which is the chemical most widely used in water treatment for the removal of colloidal materials responsible for turbidity.

e. Sodium Hydroxide (NaOH) - often called "caustic soda" is infrequently used alone in water treatment. It is used extensively to maintain pH within ranges at which precipitation occurs.

Four of these chemicals were alkaline and they reacted in water as bases; aluminum sulfate however formed small amounts of sulfuric acid in an aqueous solution. In order for it to function as a coagulant, slurries containing aluminum sulfate must be adjusted to a pH at or near the neutral point; one of the recommended alkalies for such use is sodium hydroxide.

The reagents were rated as to the amount of coagulation obtained by adding varying quantities on the following scale: None = -, Slight = +, Moderate = ++ and Maximal = +++.

Clarifier Filter:

A clarifier filter as suggested by Popper (9) was designed and evaluated in both the laboratory and commercial phases.

Treated Brine Examinations:

The treated brine was examined according to the same procedures as detailed under raw brine examination. Two analyses not performed on the treated brine were total acidity and suspended solids. Both of these characteristics were removed by the treatments.

Activated Carbon:

The Calgon Corporation, Calgon Center, Pittsburg, Pennsylvania, furnished 120 pounds of their granual activated carbon "Filtrasorb 400". This carbon was carefully washed to remove fines and approximately ten pounds dry weight were filled into a polyethylene vessel 10 X 9 X 5.5 inches providing 495 cubic inches of carbon bed. No attempt was made to determine adsorption isotherms because they would vary widely even within a single tank yard and with the efficiency of the clarifier filter.

Commercial Phase

At the commercial pickling plant, treatments which produced the optimum results in the laboratory were evaluated. Treatments were carried out in 250 gallon lots in both wooden and polyethylene containers.

Raw Material Examination:

The raw brines were visually inspected and assayed for pH and salt content as previously described. Settleable solids were determined with the aid of Imhoff cones and turbidity was measured with a Hach colorimeter.

Clarifier Filter:

The clarifier filter as previously described was evaluated as well as an activated charcoal filter. These units were used as contiguous treatments.

Treated Brine Examination:

The treated brine was examined in the same manner as the raw brine. A final treatment was also made to adjust the brine pH back to neutral with hydrochloric acid (HCl). The neutralized brine was then used to cure cucumbers.

Evaluation of Pickle Quality:

Cucumbers were cured following procedures in use by the commercial firm in both recycled brine and brine using new salt. Since the curing began in late September, the fermentation process proceeded slowly. Measurements were made of acidity, salt content and texture during the curing operation.

RESULTS AND DISCUSSION

Since the research was conducted in two phases, the results of these phases will be presented and discussed separately.

Laboratory Phase

Upon receipt of the raw brine, aliquots were taken and analyses were performed as previously mentioned. The results are given in Tables 1 & 2.

Raw Material Examination:

Table 1. Average pH and Total Acidity with Visual Observations by Salt Content of Raw Spent Brine

Salt Content	$\bar{X}$ pH	$\bar{X}$ Total Acid, as lactic	Visual Observations
°Salometer		%	
70	3.4	0.61	Very turbid greenish color
50	3.8	0.68	Turbid greenish yellow color

The 70° salometer brine was lower in pH and total acid (Table 1). The differences were expected since it has been the contention that higher salt concentration suppressed lactic acid fermentation organisms (38).

Table 2. Average Percent Suspended, Volatile, Non-Volatile and Total Solids by Salt Content of Raw Spent Brine

Salt Content	Suspended Solids*	Volatile Solids*	Non-Volatile Solids*	Total Solids*
°Salometer	%	%	%	%
70	0.71	1.10	22.51	23.67
50	0.19	1.20	14.82	15.75

* Average of 8 replicates

The 70° salometer brine had a slightly higher volatile solids content and a greater percentage of non-volatile and total solids (Table 2). The startling difference in the brines is in suspended solids. There are several explanations for this phenomena: (a) the 70° salometer brine had been holding cucumbers for about one year while the 50° salometer brine was only six months old, (b) the 70° salometer brine was received in steel drums lined with polyethylene and the linings ruptured, (c) no complete analysis of spent cucumber brines was available, therefore; quantities of cucumber constituents extracted by various brine strengths is unknown, and (d) mechanical damage to the pickles as they were removed from the tank could add substantial quantities of solids to the brine.

Results of the mineral analysis will be presented with that for the treated brines. The raw spent brine contained an average of 7,000 ppm C.O.D. and 0 ppm D.O., as would be expected. Protein and carbohydrate spot tests were both positive. Light transmission data will be discussed separately.

Coagulant Screening Tests:

A series of screening tests were performed for each of four reagents commonly used in water purification. In addition, combinations of agricultural lime and sodium carbonate were evaluated. The results (Table 3) can be summarized as follows:

1. Agricultural lime at concentrations between 2500 and 16,250 ppm and aluminum sulfate at 100 to 4000 ppm were not effective coagulants.
2. Sodium carbonate was effective in the 4300 to 4600 ppm range.
3. Calcium oxide was effective in the 1000 to 2000 ppm range but was expensive.
4. Sodium hydroxide was effective on both 50° and 70° salometer brines and was inexpensive.
5. The combination of agricultural lime and sodium carbonate produced coagulation only at the highest concentration.

Table 3. Evaluation Screening of Standard Water-Treatment Reagents for Coagulation of Suspended Solids in 70° Salometer Brine

Calcium Oxide		Sodium Hydroxide		Sodium Carbonate		Agricultural Lime and Sodium Carbonate		
conc. ppm	result[a]	conc. ppm	result[a]	conc.	result[a]	conc. ppm	conc. ppm	result[a]
100	--	1,000	--	3,120	--	2,500	1,000	--
200	--	1,200	--	3,328	--	3,750	1,000	--
300	--	1,400	--	3,536	--	5,000	1,000	--
400	--	1,600	--	3,744	+	6,250	1,000	--
500	--	1,800	+	3,952	+	2,500	2,000	--
600	--	2,000	+++	4,160	++	3,750	2,000	--
700	+	1,500[b]	--	4,368	+++	5,000	2,000	--
900	+	1,900[b]	--	4,576	+++	6,250	2,000	--
1,000	++	2,100[b]	+	4,784	++	2,500	3,000	--
1,100	+++	2,300[b]	++	5,200	+	3,750	3,000	+
1,200	+++	2,500[b]	+++	5,408	--	5,000	3,000	+
						6,250	3,000	++

[a] Coagulation: None, --; Slidht, +; Moderate, ++; Maximal, +++.

[b] 50° Salometer Brine.

6. There was no coagulation with any reagent until a pH of 6.8 was reached with maximum coagulation occurring at pH 11.0.
These results were used as a basis for enlarged tests for treatment of brine.

Clarifier Filter:

A clarifier filter was utilized with larger quantities of spent brine. Several filter materials were evaluated including: monofilament polypropylene, multifilament polypropylene, cotton and cotton precoated with a filter aid. Of these materials, the precoated cotton hose performed best under laboratory conditions.

When the brine was adjusted to pH 11.0 with sodium hydroxide, the precoated cotton hose aided in removing the coagulated residue completely. This treated brine was then passed through a filter bed of activated charcoal. The resultant brine was crystal clear and colorless. A final treatment with HCl was given to adjust the pH to neutral. This adjustment chemically produced additional salt as:

$$HCl + NaOH \rightarrow NaCl + H_2O$$

Treated Brine Examination:

Since all treatments involved pH adjustments the treated brine pH will not be given in tabular form. The color of the treated brine was bright yellow to clear. Salt concentration was essentially the same as the original brine.

The total solids were reduced slightly, about 1%, with the majority of total solids being non-volatile. Precipitation evidently removed some volatile solids as well as suspended solids.

The removed suspended solids were analyzed for plant nutrient content; i.e., minerals (Table 4).

There are several items worth mentioning from the data in Table 4. Note the iron content of the 70° salometer raw brine. As was previously mentioned, this brine was obtained in steel drums and the polyethylene liner burst. Iron corrosion is readily indicated.

Nitrogen content was reduced by all treatments. This related to the partial or complete reduction of protein content in the brines.

The most interesting aspect is the consistency of the sodium data indicating essentially no removal of sodium. This is in agreement with the salt concentration data.

The C.O.D. of the treated brines was reduced by 50% by the poorest treatment. The treatment which was best reduced C.O.D. to an average of 200 ppm or by more than 97%.

As reported for raw brine, the D.O. of treated brines was 0.

Table 4. Suspended Solids, Plant Nutrient Analysis

Sample	P %	K %	Ca %	Mg %	Na %	Si %	Mn ppm	Fe ppm	Bo ppm
1. 50° Salometer Raw Brine	0.08	0.30	0.10	0.03	0.23	0.05	11	40	8
2. 70° Salometer Raw Brine	1.47	0.32	0.63	0.09	0.15	0.43	128	3845	15
3. 50° NaOH precipitate at pH 9.0	0.08	0.31	0.10	0.03	0.23	0.05	10	39	7
4. 50° CaO precipitate at pH 9.0	0.08	0.30	0.10	0.03	0.23	0.05	10	39	7
5. 70° NaOH precipitate at pH 7.2	0.11	0.30	0.10	0.03	0.24	0.03	10	645	7
6. Sample 3 A/C^a filtered	0.08	0.30	0.10	0.03	0.23	0.05	10	38	6
7. Sample 5 A/C^a filtered	0.09	0.31	0.10	0.03	0.24	0.06	10	41	8
8. Completely treated brine	0.10	0.35	0.10	0.03	0.20	0.02	10	44	8

Table 4 (continued)

	Sample	Cu ppm	Zn ppm	Al ppm	Sr ppm	Ba ppm	Mo ppm	N_2 %
1.	50° Salometer Raw Brine	5	12	13	22	3	0.25	0.075
2.	70° Salometer Raw Brine	17	198	701	38	10	2.7	3.3
3.	50° NaOH precipitate at pH 9.0	5	11	12	20	3	0.22	0.060
4.	50° CaO precipitate at pH 9.0	5	11	12	21	3	0.20	0.080
5.	70° NaOH precipitate at pH 7.2	5	11	26	25	3	0.19	0.30
6.	Sample 3 A/C[a] filtered	5	12	11	21	3	0.17	0.035
7.	Sample 5 A/C[a] filtered	5	13	12	20	4	0.32	0.058
8.	Completely treated brine	13	11	25	24	3	0.51	0.015

[a] A/C = activated carbon

The light transmittance data (Table 5) give an indication of turbidity as well as efficiency of suspended solids removal. This test is rather simple and could be used "in-plant" as an evaluation or control technique.

The spot tests also were useful in determining efficiency of removal of carbohydrate and protein. These data are presented in Table 6. It should be noted that the ideal treated brine would be negative for both tests. These tests would also be useful "in-plant" tools.

The micro-Kjeldahl tests confirmed the results of the spot tests (Biuret).

With these results, the commercial scale tests were then conducted.

Commercial Phase

At the commercial plant aliquots of spent brine were titrated with NaOH. By ratio, calculations were made as to the amount of NaOH to add to the tanks for precipitation at pH 11.0. The raw brine was also examined for turbidity and settleable solids.

The treated brines were pumped through the clarifier filter and activated charcoal filter. Needless to say, there were some mechanical difficulties but these were overcome rapidly and a workable system resulted. However, after assaying cost of pumping, filtering, and activated charcoal. It was decided that these steps could be eliminated by allowing the precipitate to settle and then decanting the liquid brine. Settling periods of 24 and 48 hours were utilized. In addition duplicate treatments with and without diatomaceous earth were evaluated.

Table 7. Turbidity and Settleable Solids of Raw and Treated Brines

Treatment	Turbidity*	Settleable Solids
		ml.
1. Raw Brine	820	200
2. Settled 24 hrs.	180	0
3. Settled 24 hrs. & Celite	120	0
4. Settled 48 hrs.	85	0
5. Settled 48 hrs. & Celite	75	0
6. #2 pH adjusted to 7.0	132	0
7. #3 pH adjusted to 7.0	90	0
8. #4 pH adjusted to 7.0	58	0
9. #5 pH adjusted to 7.0	50	0

*Turbidity is expressed in Jackson Turbidity Units.

On the basis of the results (Table 7), a 48 hour settling period produced the best results. Spot tests on this brine indicated carbohydrate present but no protein. Although, it has not been definitely identified, the carbohydrate was possibly a pigmented artifact since pH adjustments

Table 5. Turbidity Comparison of 50° Salometer Brine as Percent Light Transmittance

Sample	Wave Length (nanometers)						
	375 %	380 %	390 %	400 %	410 %	430 %	580 %
1. Raw Brine	--	15.3	--	19.4	--	--	23.5
2. NaOH precipitation at pH 11.0	39.0	42.4	48.8	55.5	66.0	77.5	98.0
3. NaOH coagulation at pH 11.0 + clarifier filter	55.5	59.0	64.2	67.6	72.1	80.2	98.0
4. CaO coagulation at pH 11.0+ clarifier filter	43.2	46.0	52.5	57.5	64.8	75.0	96.2
5. Sample 2 A/C[a] filter	100.0	100.0	99.5	100.0	100.0	100.0	100.0
6. Sample 3 A/C[a] filter	90.6	91.5	93.2	93.6	95.0	98.1	100.0
7. Sample 4 A/C[a] filter	93.0	92.5	94.2	95.2	96.0	97.5	100.0

[a] A/C - Activated Charcoal

Table 6. Molisch Carbohydrate and Biuret Protein Spot Tests 50° Salometer Brine

Sample	Carbohydrate Reaction	Protein Reaction
1. Glucose solution	Pos.	
2. Pectin solution	Pos.	
3. Distilled water blank	Neg.	Neg.
4. Casein solution		Pos.
5. Zein solution		Pos.
6. pH 8.7 clarifier filtered brine	Neg.	Pos.
7. pH 11.0 clarifier filtered brine	Spoiled	Pos.
8. pH 11.0 clarifier filtered and A/C[a] filtered brine	Neg.	Neg.
9. pH 11.0 clarifier filtered, A/C[a] filtered, and pH readjusted to 11.0	Neg.	Neg.
10. pH 11.0 clarifier filtered, A/C[a] filtered, and pH readjusted to 7.0 with HCl	Neg.	Neg.
11. Scale model completely treated first fraction	Neg.	Neg.
12. Scale model completely treated final fraction	Neg.	Neg.
13. Centrifuged solids from scale model sludge trap	Tr.	Pos.
14. Centrifuged solids from coagulated clarifier filter	Tr.	Pos.
15. Centrifuged solids from completely treated brine	Neg.	Pos.

[a] A/C = Activated Charcoal

changed the intensity of the color of the brine. It was not a fermentable sugar.

As mentioned earlier, cucumbers were obtained in late September. These fruits were obtained three weeks after the close of the season and as a result many were overripe. This stock was divided into nearly equal lots of 71 and 72 bushels. One lot was placed in the diluted recycled brine and the other was placed in brine made from "new" salt. These tanks were examined periodically.

Table 8. Comparison of Salt Stock Pickles Made from Recycled Brines and Fresh Brines as Determined Jan. 30, 1973.

Attribute	Fresh Brine	Recycled Brine
Lactic Acid	0.52%	0.54%
Salometer	52.5°	52.5°
Pressure test (ave.)	11.7	13.3
Color	normal	normal
Percent of Cure	50%	65%

The data in Table 8 indicate that using recycled brine was not detrimental to pickle fermentation. It should be noted that this phase took place after the proper season for curing cucumbers. The most important aspect is that the fermentation took place and the pickles in recycled brine were as good as the pickles in the fresh brine. This encouraging result will be re-evaluated during the coming season.

SUMMARY AND CONCLUSION

Based on the data obtained it appears that salt brines can be recycled without deleterious effects on the salt stock pickles. The cost of treating brine for 100,000 bushels of cucumbers using this method is $1450. However, for this volume of cucumbers a savings of 3100 cwt of salt would be realized. Using $1.00 per cwt as a cost for salt, recycling the brines represents an actual savings of $1650. This figure does not include savings on sewage costs and surcharges.

The recommended system for salt brine recycling includes:

1. Adjust pH to 11.0 with sodium hydroxide
2. Allow 48 hour settling period
3. Decant clear brine
4. Adjust pH to 7.0 with hydrochloric acid
5. Brine is ready for reuse
6. Precipitate could be incinerated to recover any salt present and reduce disposal problems.

Several quick tests were used in this study which could be used in-plant. Investigations are underway to develop a closed loop system for pickle manufacture.

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Use of Yeast in the Treatment of Sauerkraut Waste

by

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Introduction

Sauerkraut is a clean, sound product obtained by the lactic acid fermentation of properly prepared and shredded cabbage in the presence of 2 to 3% salt. It contains, on the completion of the fermentation, at least 1.5% titratable acidity expressed as lactic acid. In 1970, New York State produced over 3.4 million cases of sauerkraut - about 40% of the total production of this product in the United States.

Both solid and liquid wastes are generated in the manufacture of sauerkraut (Figure 1). Trim losses (solid waste) were over 35 tons per 100 tons of raw cabbage processed in 1971. The discarded brines are a significant source of liquid waste, representing a loss of about 29% of the salted, shredded cabbage (1). In addition to brines, other sources of liquid waste are the vat soak water, vat wash water, and cooling water. The volume and composition of these different wastes have been reported (1). The waste effluents were very strong with a biochemical oxygen demand (BOD) as high as 41,000 mg/1. In addition to their strength, they often contained as much as 4% salt and a titratable acidity, expressed as lactic acid, of 2% or more. They therefore do not lend themselves to treatment in conventional sewage systems and thus there is a real need for improved methods of treatment or utilization of this waste effluent.

Yeasts have been used to solve waste disposal problems with the concomitant production of desirable products (2). The objective of this work was to evaluate the treatability of sauerkraut waste effluent using a food yeast, *Candida utilis* NRRL Y-900.

Experimental

The sauerkraut waste effluent used in this work was brine collected from a vat containing 8-week old sauerkraut. Brine of this age has been termed by us "late brine" (1). It was stored at 0°C until the tests and fermentations could be made.

Experiments were carried out at 25°C in a 7-1 fermentor containing 5 1 of wastewater. Aeration was achieved by sparging the air into the system at a rate of one volume per volume of wastewater per min. The impellers were operated at a speed of 1000 rpm. Treatment studies were initiated by adding a 22-hr yeast culture at a level of 2% (v/v). Samples were then withdrawn at different time intervals, for the determination of 5-day BOD, total acid as lactic, Kjeldahl nitrogen, total phosphorus, and cell dry weight (1). The oxygen uptake rate of the yeast grown in the wastewater was determined by the method of Young and Baumann (3).

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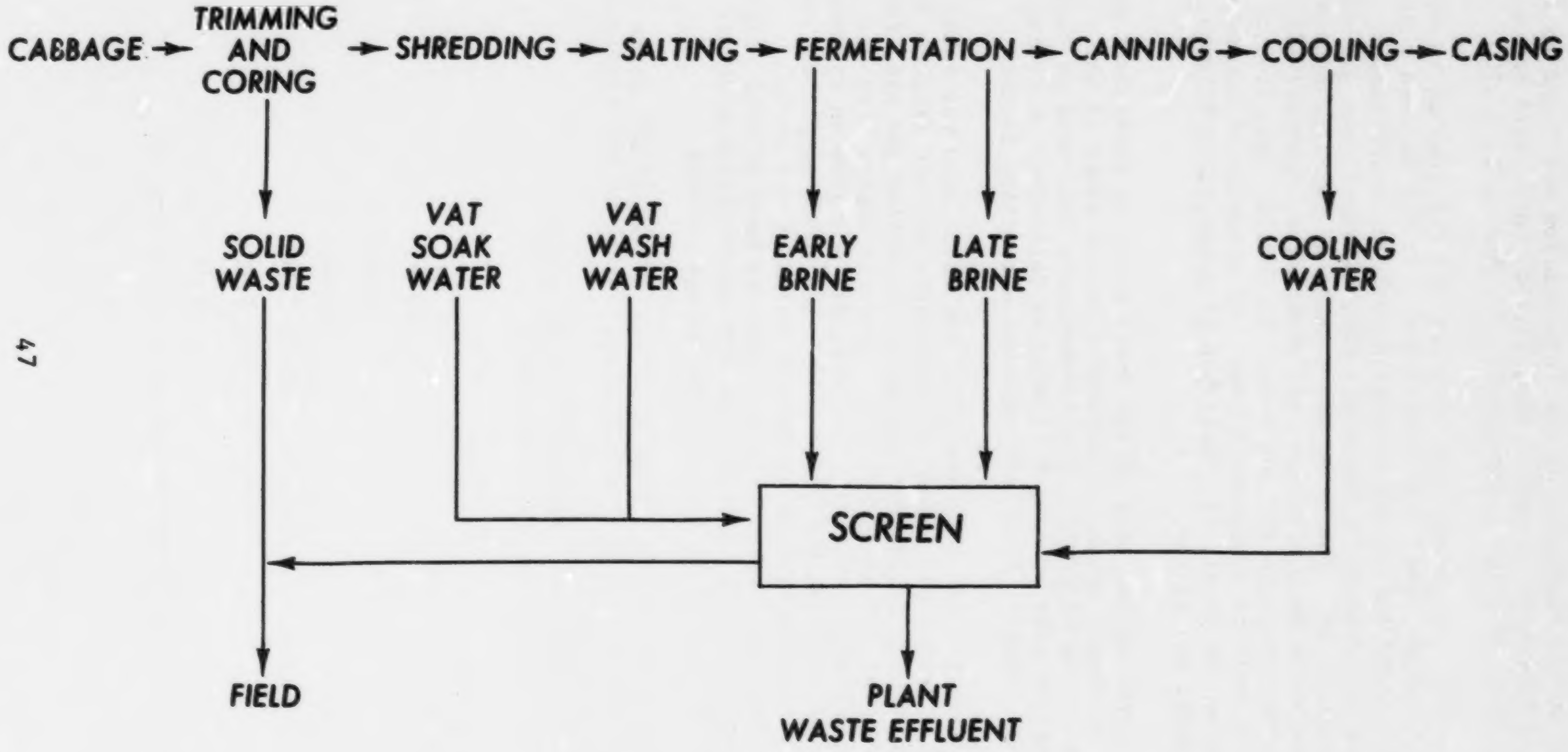
CABBAGE
TRIMMING AND CORING
SHREDDING
SALTING
FERMENTATION
CANNING
COOLING
CASING
SOLID WASTE
VAT SOAK WATER
VAT WASH WATER
EARLY BRINE
LATE BRINE
COOLING WATER
SCREEN
FIELD
PLANT WASTE EFFLUENT

Figure 1. Wastes generated in the manufacture of sauerkraut.

Results and Discussions

The sample collected at the beginning of the fermentation was found to contain the following expressed as mg/l: BOD, 11,750; total acid as lactic, 7,200; Kjeldahl nitrogen, 560; total phosphorus, 75; and NaCl, 17,700.

The data in Figure 2 show the growth rate of yeast and the removal rates of the waste BOD, Kjeldahl nitrogen, and total phosphorus. It can be seen that approximately 10 hr elapsed before exponential growth was established. The most rapid growth and removal of the waste BOD, nitrogen, and phosphorus occurred between 10 and 16 hr. The yeast was capable of removing approximately 80, 70 and 90% of the waste BOD, nitrogen, and phosphorus, respectively, in 16 hr. Prolonged fermentation did not result in further reduction of the waste strength. This could be explained by the: a) presence of compounds not readily utilized by the yeast, b) depletion of essential nutrients, or c) accumulation of toxic substances.

Figure 3 shows the oxygen uptake rate of the yeast grown in sauerkraut waste effluent. The rate of oxygen uptake calculated from the slope of the straight line equals 2.7 mg O_2/l/min. The fermentation unit used in this work provided an aeration rate of 4 mg O_2/l/min, as determined by sodium sulfite oxidation (4). Oxygen, therefore, was not a limiting factor.

The optimum rate of aeration for the removal of the waste acid was found to range from 0.75 to 1.0 volume per volume of wastewater per min (Figure 4). At aeration rates below 0.75 volume per volume of wastewater per min, the rate of waste acid removal decreased sharply. Aeration higher than one volume per volume of wastewater per min, however, did not give an appreciable increase in the rate of removing the waste acid. The yeast completely neutralized the acid and raised the pH from an initial value of 3.5 to 7.3 at 16 hr when the fermentation was complete. This may have economic significance since acid waste effluents generally require neutralization before they can be effectively treated in conventional sewage systems.

The yield of yeast cells was greater than 65 lb per 100 lb of the waste BOD removed. The protein content of the yeast was approximately 41% (Table 1).

Table 1. Chemical composition of *C. utilis* grown in sauerkraut waste

	%
Protein	40.80
Fat	0.65
Carbohydrates	43.41
Ash	6.18
Fiber	6.20
Moisture	2.76

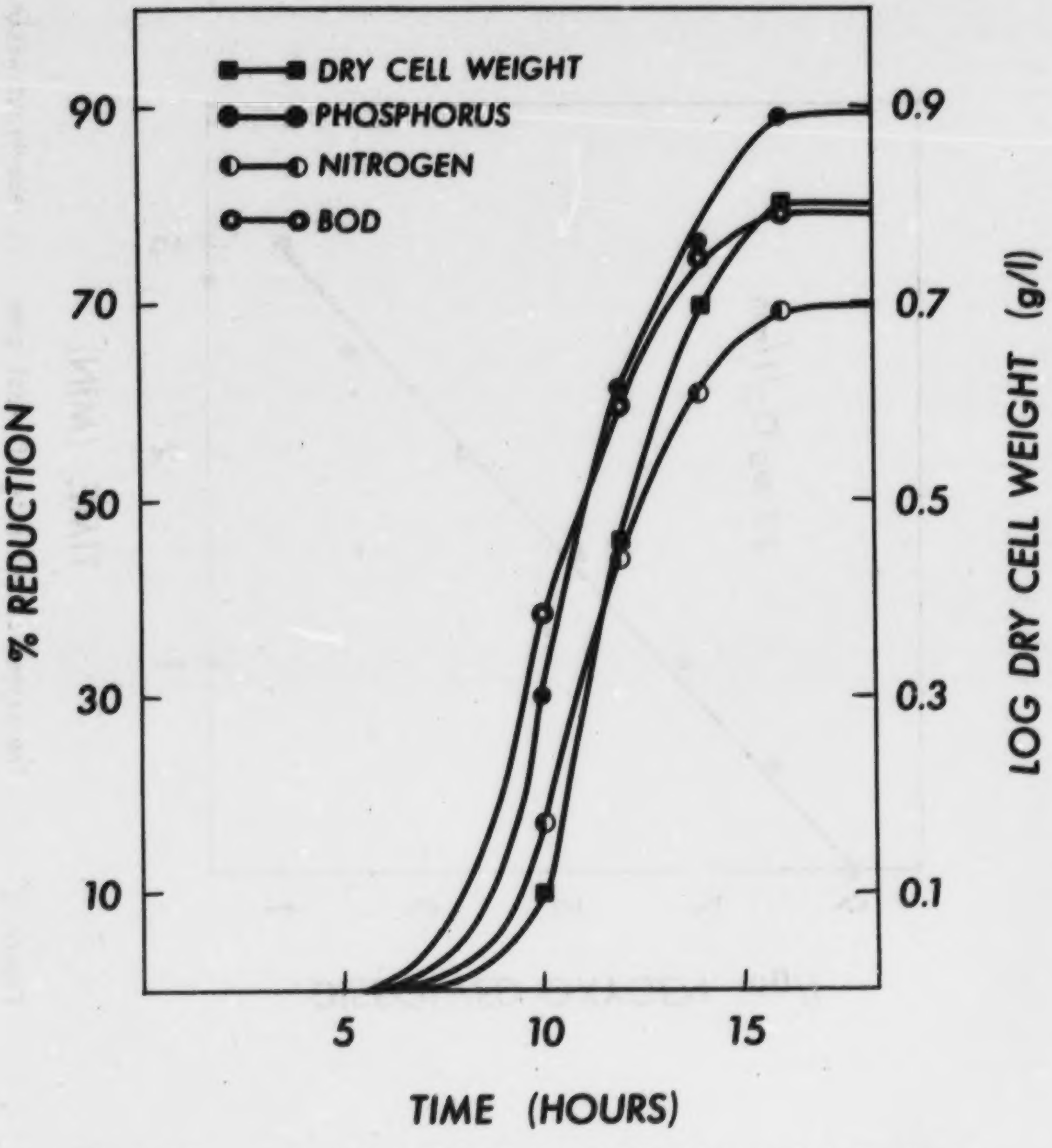

Figure 2. Removal rates of the waste BOD, nitrogen and phosphorus by yeast

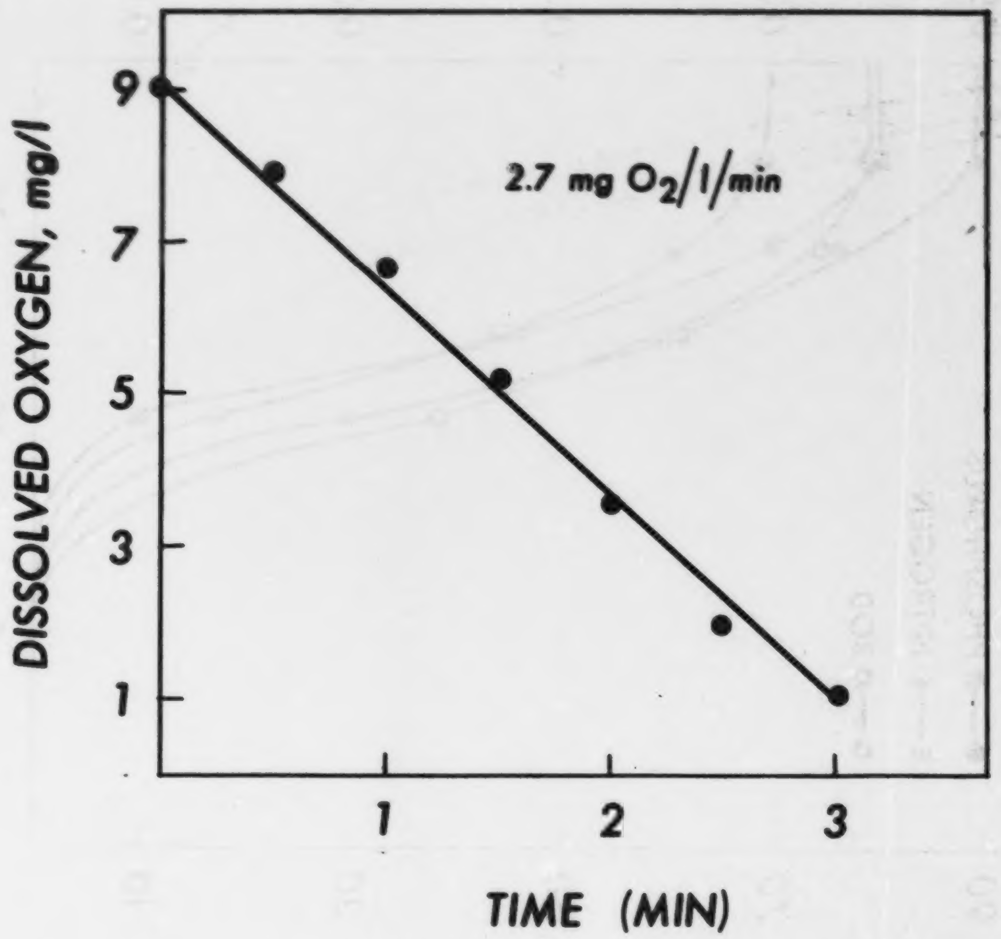

Figure 3 The oxygen uptake rate of yeast grow in sauerkraut waste.

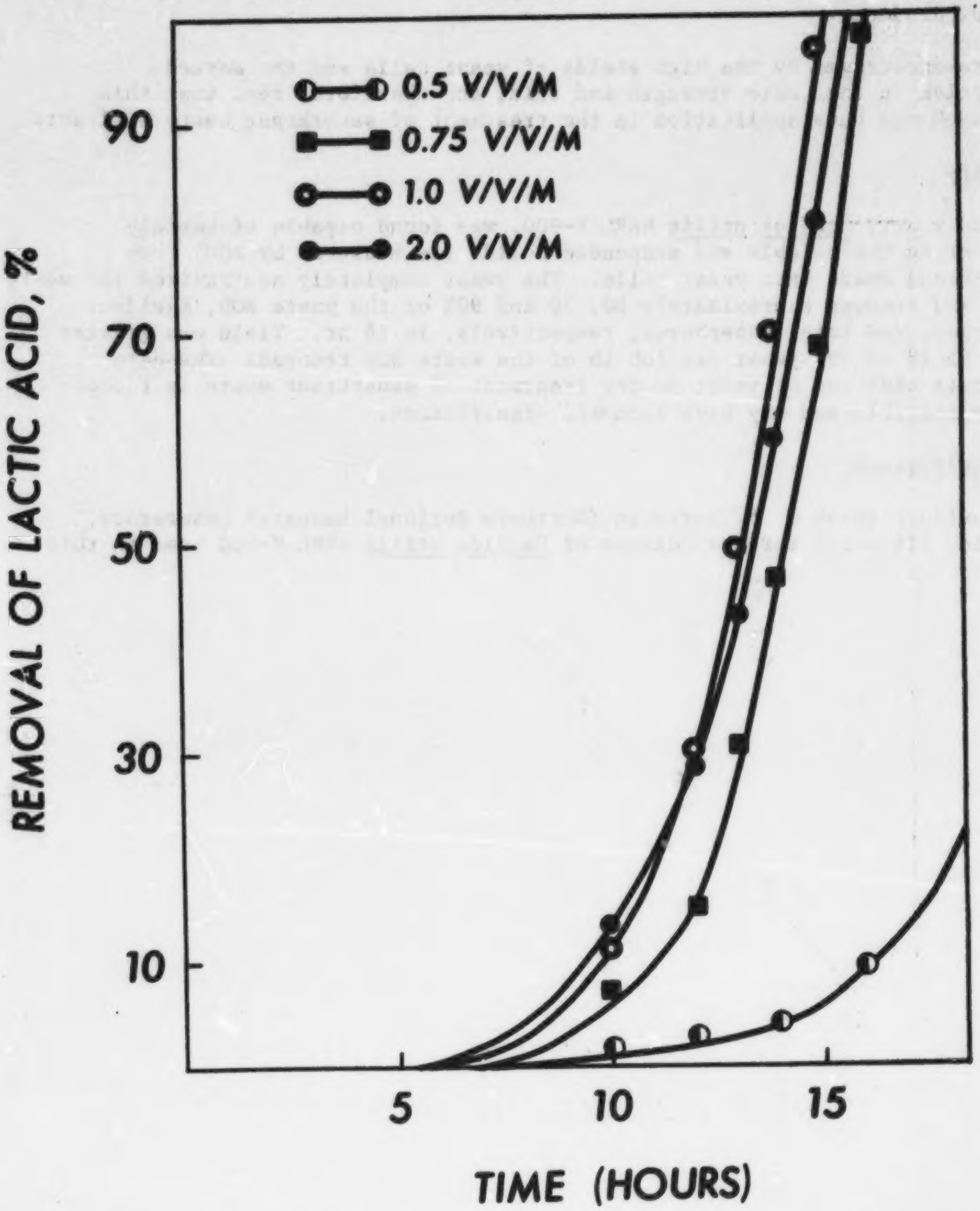

Figure 4 Effect of aeration rate on the removal of the waste acid by yeast.

In addition, the yeast cells have been found to be an excellent source of invertase, producing 672,000 units per g of dried yeast (5). This enzyme has various uses in food industries such as for the hydrolysis of sucrose in molasses. The data thus indicate that sauerkraut waste could be used as a medium for the production of food yeast, invertase, and perhaps other useful products.

We are encouraged by the high yields of yeast cells and the marked reduction in the waste strength and acid, and therefore, feel that this approach may have application in the treatment of sauerkraut waste effluent.

Summary

A food yeast, Candida utilis NRRL Y-900, was found capable of rapidly converting the soluble and suspended solids (as measured by BOD) from sauerkraut waste into yeast cells. The yeast completely neutralized the waste acid and removed approximately 80, 70 and 90% of the waste BOD, Kjeldahl nitrogen, and total phosphorus, respectively, in 16 hr. Yield was greater than 65 lb of dry yeast per 100 lb of the waste BOD removed. The data indicate that use of yeast in the treatment of sauerkraut waste is technically feasible and may have economic significance.

Acknowledgement

The authors thank C. P. Kurtzman (Northern Regional Research Laboratory, Peoria, Illinois) for the culture of Candida utilis NRRL Y-900 used in this work.

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REDUCED-WATER CLEANING OF TOMATOES

by

J. M. Krochta, G. S. Williams, R. P. Graham and D. F. Farkas*

INTRODUCTION

Concern over water consumption and pollution has touched the food-processing industry at least as deeply as other sectors of the economy. Large amounts of water are consumed during processing steps involving raw material cleaning, in-plant transfer, peeling, blanching, cooling and segregation. In addition, these steps add large amounts of total solids, suspended solids, and BOD to the water. Studies of the effluents of canneries(1,2,3,4) have shown consumptions of from 100 to 9,000 gallons of water per ton of raw material in the course of processing, with the majority producing from 500 to 3,000 gals/ton. Analyses of these streams have revealed total solids, suspended solids, and BOD ranging up to 600, 50, and 200 lbs/ton raw material, respectively.

Important technological advances in the last two years have significantly reduced the pollution loads from peeling(5,6,7) and blanching(8,9). The approach in these cases has been to alter the process in such a way that water consumption and pollution are reduced, rather than treat the resultant waste streams. In the work described here, this same philosophy has been applied to the cleaning process.

Cleaning

Most present day cleaning includes one or more of the following methods: dry screening, pneumatic cleaning, agitated water baths, water flumes, or water sprays. Aside from recommendations for greater use of screening, air cleaning, high-pressure low-volume water sprays, counter-flow water use, water recirculation and pneumatic and mechanical conveying, little in the way of new cleaning methods has been proposed to reduce water use and pollution. Depending on the commodity, studies(2,3,4) show that cleaning can account for effluent flows of 100-2,000 gals/ton raw material, total solids of 5-25 lbs/ton, suspended solids of 2-20 lbs/ton and BOD values of 0.5-20 lbs/ton. These amounts can represent a significant portion of the effluent from the entire process.

Cleaning Tomatoes

In the case of tomatoes, measurements and estimates of water used in cleaning are in the range 400-2,000 gals/ton; with estimates of suspended solids and BOD from cleaning at 50% of that from the entire process(4). This situation

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has been aggravated in recent years by mechanical harvesting, which has increased both breakage and soil contamination of tomatoes. It is not unusual for the canner to receive loads having 33% broken tomatoes. This compares with approximately 10 percent damaged with hand picking. Soil loads on machine picked fruit have been found to be close to 2%, with 10% of the soil present as a difficult-to-remove smear(10). These factors lead to greater water consumption as well as greater pollution due to leakage from the broken tomatoes and a high concentration of suspended soil.

The Cleaning Process

Soiling is a spontaneous process with a negative change in free energy. Therefore, a certain amount of energy is required to produce a clean surface. Usually, flowing water provides the energy for removing soil. At the same time, it is the medium for soil dispersion and transport away from the cleaned surface. Tomato cleaning is usually accomplished by a combination of agitated baths, flumes and water sprays. New methods are needed for introducing the energy required for soil removal, decreasing the energy requirement, dispersing the soil and transporting soil away from the surface, if water consumption and pollution from tomato cleaning are to be reduced.

This paper reports an initial evaluation of mechanical cleaning using rubber disk wipers, in conjunction with either foam or water mists, to remove soil from tomatoes. Previous mechanical means in cleaning fruits and vegetables have been limited by the inability of devices to handle varying sizes of material, by excessive damage of product, and by buildup of soil on the equipment. Rotary rod type washers which utilize tumbling and rubbing action are sometimes employed to help clean root vegetables. Brushes are also utilized in the cleaning of root vegetables. Foams have been developed and used in the cleaning of hard surfaces on vehicles, processing equipment, and in food plants(11,12). Foam offers the advantage of being economical of water because of its expanded nature. Furthermore, foam clings to surfaces rather than running off to waste. As a result, large areas can be covered with a small amounts of water, with moisture available to the surface for a period of time. Foams can be generated with surfactants reported effective in improving cleaning of fruits and vegetables(13), and they are effective in suspending small particles.

Our approach was to determine the effectiveness of mechanical wiping in the cleaning of tomatoes on a pilot scale. This consists of a pre-application of a foam or water mist followed by mechanical wiping of the soiled surface to distribute the foam or water. Continued wiping loosens and then suspends the soil in the medium used and finally removes the soiled solution from the tomato surfaces.

EXPERIMENTAL

Process and Equipment Description

Three steps are usually employed in applying the concept of mechanical wiping to cleaning tomatoes: A water bath dump, a foam or water mist application with mechanical wiping, and a spray rinse.

(1) Water bath dump. This is done to simulate the dumping operation conventionally performed to reduce further damage in transferring tomatoes from harvest bins to the tomato processing lines, and to initiate the cleaning process. In a typical operation, the tomatoes are then flumed from the dump tank to a second agitated bath or flume. The residence time of each agitated bath or flume is normally 30-60 sec. However, in the mechanical cleaning process this step is held to a 5-10 sec. residence time. In this way the dump and removal of loose soil are accomplished while limiting the leaching of broken tomatoes into the water. This operation is performed by dumping tomatoes by hand from baskets into a small stainless steel tank. An elevator conveyor is positioned in the tank, and, with the dumping rated used, a 5-10 sec. residence time occurs before elevation from the tank. In some instances this step is omitted and the tomatoes are put directly through the next step.

(2) Foam or water mist application and wipe. The long residence time of tomatoes during conventional cleaning in agitated baths and flumes is intended to remove tightly adhering smear soil from smooth surfaces, crevices and breaks. The second step of the mechanical cleaning process essentially replaces long exposure to the turbulent action of water with short exposure to the vigorous mechanical wiping action of soft rubber disks. The large volumes of water usually used are replaced with foam or a water mist. The dry caustic rubber disk peeler concept developed by the Western Regional Research Laboratory(7) was adapted to clean tomatoes in combination with foam or water mist. The unit, which is 8 in. wide and 6 ft. long, is pictured in Figure 1 with one of the side panels removed. Neoprene rubber disks with 4-1/4 in. diameter, mounted 1 in. apart on 1/2 in. stainless steel shafts, are employed. The rubber disks are 1/4 in. thick to a radius of 1-3/8 in., narrow down to 1/32 in., then widen to 1/4 in. the last 1/8 in. of radius. Plastic spacers 3/4 in. thick and with 1-5/8 in. diameter separate the rubber disks. The shafts are parallel to each other and 3 in. apart, thereby providing 1-1/4 in. overlap between rows of disks. The disks are spun in the direction of product movement by gearing the shafts to a drive chain. The unit is operated with an upward incline of 7 in. over its 6 ft. length. As the tomatoes move onto the spinning disks, they are sprayed with either a foam, as shown in Figure 2, or a fine water mist. The spinning, moving and wiping action of the rubber disks moves tomatoes through the unit, loosens and suspends the soil in the cleaning medium, and throws the heavily soiled water into a tray located beneath the disks over the length of the device.

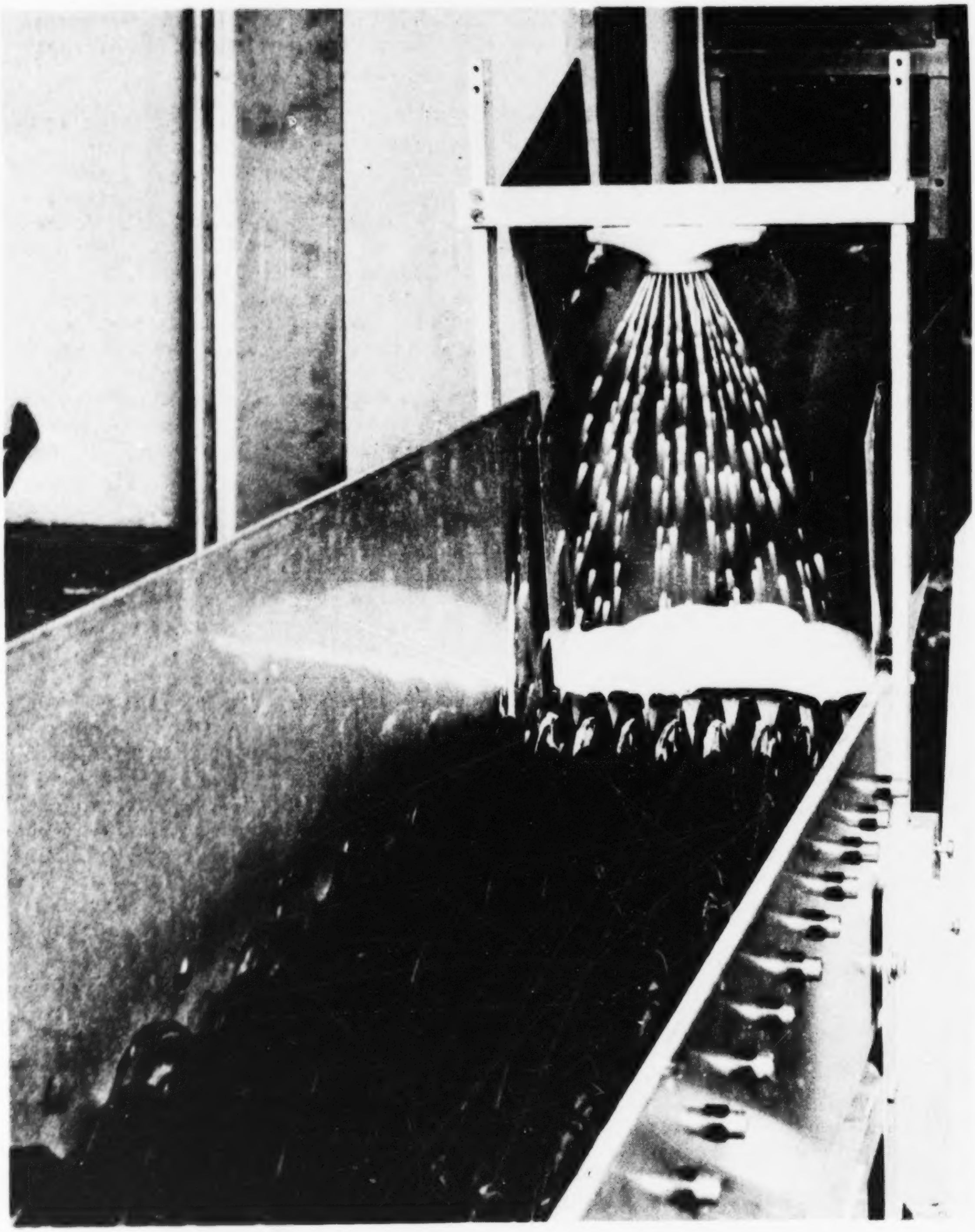

Figure 1. Mechanical cleaning unit showing wiper disks and foam spray.

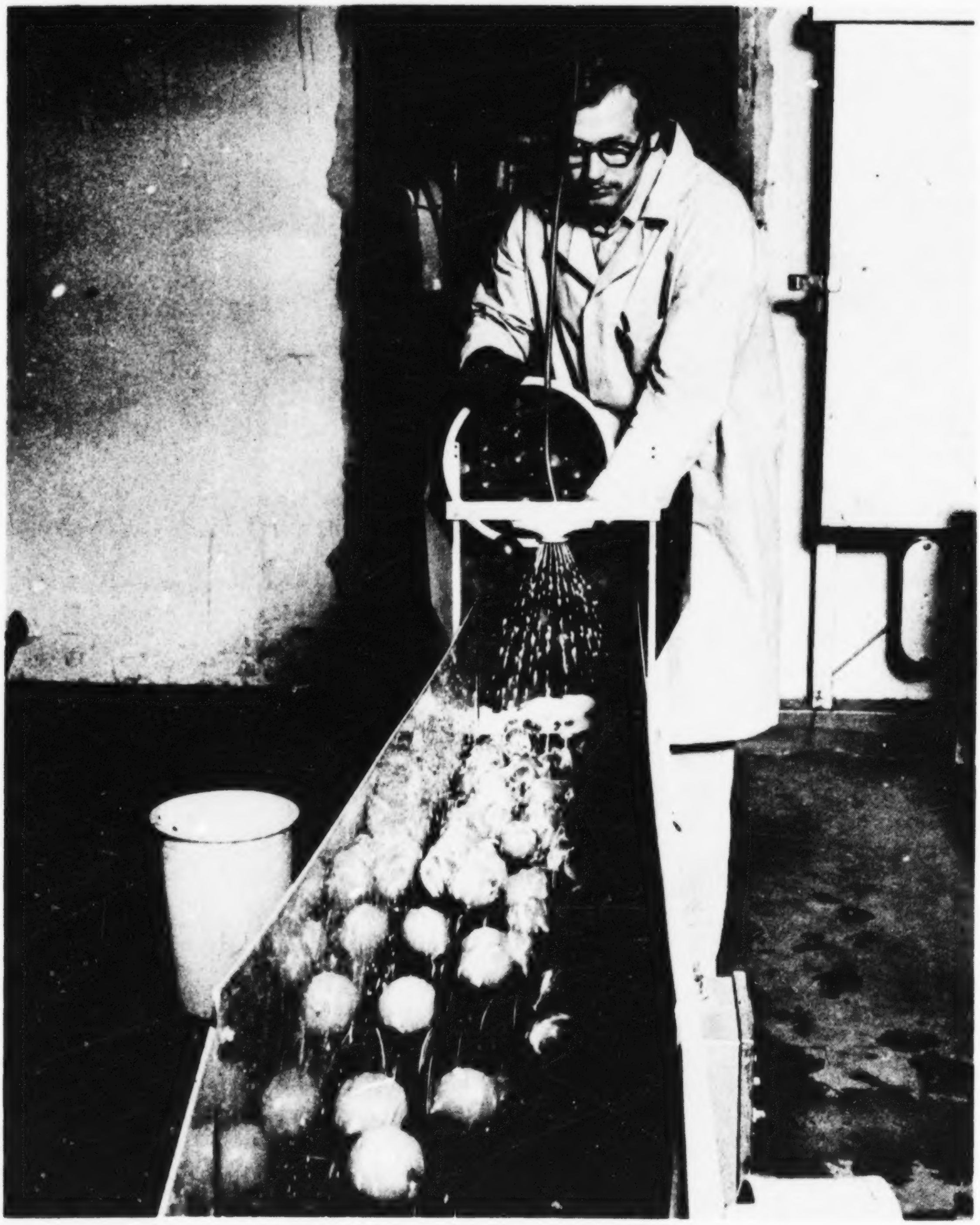

Figure 2. Mechanical cleaning unit in operation using foam spray.

Foam is generated by any suitable means by metering a solution of surfactant and compressed gas to a foam generator. The foam is applied to the tomatoes through a simple garden spray shown in Figures 1 and 2. Water mist is applied using a small Whirljet 1/4A2 (Spraying Systems Co.) nozzle. In the pilot scale work, tomatoes were hand carried from the water dump elevator and hand fed to the wiping device.

(3) Spray rinse. The tomatoes are given a final fresh water spray rinse while traveling on a wire mesh conveyor leading from a chute on the wiping device.

Procedure

The characteristics of foam generated using several surfactants were determined. Two anionic surfactants, sodium lauryl sulphate (Duponol C-Dupont) and sodium alkyl benzene sulfonate (Conco AAS-35S-Continental Chemical) and one nonionic surfactant, an alkanol amide (Condensate Co.-Continental Chemical) were tested. Using several concentrations, surfactant solutions were metered to the foam generator along with pressurized gas. The liquid flow was held constant at 1/2 l/min., while the gas flow rate was varied over the range 1-5 l/min. Both density and foam half-life were determined on foam produced at each condition. The half-life was defined as the time required for half of the liquid content of the foam to collapse back to the liquid state after collecting foam for 12 sec. in a 1 l. beaker.

Pilot cleaning experiments were carried out on pre-graded VF 145 tomatoes, using a feed rate of 40 lb./min. Grading was performed to determine the fraction of tomatoes for each run which were whole, split, and smashed. Splits were defined as having surface cracks which did not extend to the tomato seeds. Smashed tomatoes had damage which exposed seeds. Runs of 200-300 lb. of tomatoes were usually made. The volume of water used at each step was measured, and after each run representative effluent samples were taken from each step so that total solids, ash, suspended solids, and COD could be determined.

Analytical methods

Suspended solids were determined by filtering an effluent sample using No. 576 filter paper (Schleicher and Schuell), measuring total solids of the filtrate, and taking the difference. COD was determined by measuring total carbon of a pre-filtered sample using a Beckman Total Organic Carbon Analyzer Model 915, assuming the carbon was contributed by carbohydrates, and multiplying by 2.67 to obtain COD. The amount of soil being removed from the tomatoes at each step of the cleaning process was determined from the ash of the effluent stream at each step. The small amount of ash contributed by the tomatoes themselves is negligible. This technique was compared to direct sampling of tomatoes at each step followed by rinsing to determine residual soil, and was felt to be more accurate.

Because of the scarcity of well-defined effluent data from tomato cleaning, a conventional cleaning process was simulated to obtain data for comparison. Batches of tomatoes weighing 10-15 lb. were dumped into the agitated water bath and swirled for 30 sec. This was done until 100-200 lb. had received this treatment. After taking water samples, the cleaning water was replaced with fresh water. The tomatoes were again dumped and swirled in the same manner to simulate a second water bath or flume. The second exposure time in the water bath was 60 sec. The tomatoes received a spray rinse upon removal.

RESULTS AND DISCUSSION

Figure 3 shows the characteristics of foams generated. The results reveal that at equal weight concentrations, sodium alkyl benzene sulfonate gives the most stable foam, while alkanol amide gives the least stable foam. Foam stability increases as foam density decreases, until the surfactant is no longer able to provide a foam due to excess gas. At this point, "bumping" is observed at the foam generator outlet and foam density begins to increase as the gas rate increases. Sodium lauryl sulfate was selected for use in tomato foam-wipe cleaning experiments, since at low concentrations it produces a good foam with a reasonable half-life, has been approved for use in several food items and is on the GRAS list(14), and has good biodegradability. All cleaning experiments using foam were performed with concentrations of 100 and 250 ppm surfactant at foam densities of 0.25 g/cu. cm.

Table 1 shows typical cleaning results for each cleaning approach comparing effluent loads from simulated conventional cleaning (A:30 sec. agitated bath, 60 sec. agitated bath, rinse) three-step foam-wipe cleaning (B:5-10 sec. agitated bath, foam application and wiping, rinse), foam cleaning excluding the initial dump into an agitated bath (C), three-step mist-wipe cleaning (D:5-10 sec. agitated bath, water mist spray application and wiping, rinse) and an estimate of effluent from a conventional cleaning process(4).

Table 1. Effluent From Cleaning Tomatoes

	Total effluent load			
Process	Water gal/ton	TS lb/ton	SS lb/ton	COD lb/ton
A: Bath 1, Bath 2 and rinse	412	6.7	4.0	3.4
B: Bath, foam wipe, rinse	149	4.1	2.5	1.8
C: Foam wipe, rinse	57	2.9	1.9	1.0
D: Bath, mist wipe, rinse	149	5.0	2.5	2.1
Estimate of Conventional	1350	---	4.9	8.4

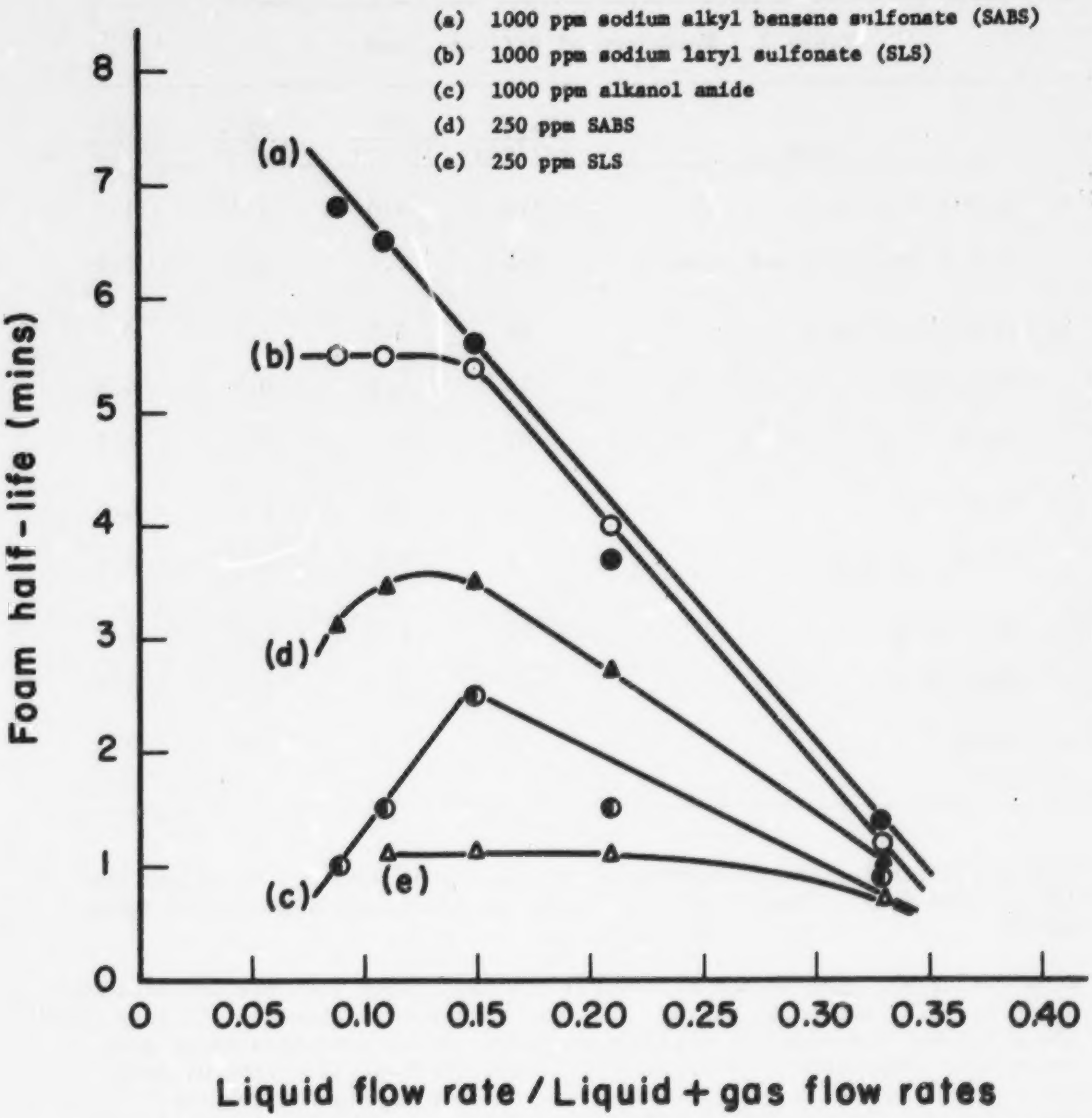

Figure 3. Effect of liquid fraction of total volume flow on foam stability with liquid flow = 1/2 l/min.

Table 2 shows the results in greater detail, giving the effluent characteristics from each step in each cleaning process.

Table 2. Breakdown of Effluent Load

Step		Water gal/ton	TS lb/ton	SS lb/ton	COD lb/ton
A:	Bath 1 (30 sec.)	176	4.0	2.8	1.2
	Bath 2 (60 sec.) and rinse	236	2.7	1.2	2.2
B:	Bath (5-10 sec.)	88	2.5	1.8	0.7
	Foam wipe	14	1.3	0.5	0.8
	Rinse	47	0.4	0.2	0.3
C:	Foam wipe	13	2.3	1.6	0.8
	Rinse	44	0.5	0.3	0.3
D:	Bath (5-10 sec.)	88	2.6	1.6	1.0
	Mist wipe	14	1.3	0.5	0.8
	Rinse	47	1.1	0.4	0.3

Tomato defects for the runs reported included approximately 7% splits and 10% smashed fruit. Smear soil was approximately 0.10% of the total tomato weight.

Considering all experiments mechanical cleaning using foam yielded effluents which had 32% less total solids, 33% less suspended solids and 41% less COD than the simulated conventional cleaning process. Results using a water mist spray were comparable to results using foam. Mechanical wiping without foam or mist was much less effective in cleaning and is not reported. Residence time on the spinning disks was 5-7 sec. with the disks spinning at 500 rpm. Incomplete cleaning was obtained when the agitated bath dump was omitted in the foam-wipe cleaning process as shown in Table 3.

Table 3. Soil Removed at Each Step

Step		% soil removed
A:	Bath 1 (30 sec.)	81
	Bath 2 (60 sec.) and rinse	19
B.	Bath (5-10 sec.)	69
	Foam wipe	25
	Rinse	6
C:	Foam wipe	81
	Rinse	14*
D:	Bath (5-10 sec.)	68
	Mist wipe	22
	Rinse	10

*5% original soil remaining on tomatoes.

Except where the initial agitated bath dump was omitted, observations of tomatoes from the last step indicated complete cleaning. The elimination of dump tanks would require a new method for large scale transfer of tomatoes from bins to processing lines and a more rigorous or longer foam wiping or rinsing process would be required.

The total volume of water used in the processes involving mechanical wiping is quite low, due in large part to the small amount of water used in the form of foam or mist with the mechanical wiping step. Water consumption could be reduced even further with re-use of final rinse water in the original water bath dump.

Table 3 shows that a somewhat greater percentage of soil was removed at the wiping step when foam was used rather than water mist. This was found generally to be the case, with the difference in the range of 4-23%. Furthermore, experiments indicated that a more efficient foam application method could reduce the amount of foam required without reducing the efficiency of the wiper device. An expanded study is planned to optimize the efficiency of the system.

Mechanical wiping increased tomato damage by about 4%. The wiping action was found effective in removing stems, with over 60% of the entering stems being removed in a single pass through the wiper. A longer unit or more time on the wipers could conceivably remove nearly all stems.

Microbiological studies were not carried out in this phase of the work since emphasis was on the demonstration of the feasibility of the process. An expanded in-plant test of this new cleaning process will include a study of the microbiology of the cleaned tomatoes in comparison with conventionally washed fruit.

The authors express their appreciation to Mr. Raymond Souza and Mr. Tom Wada for equipment fabrication, and Mrs. Joyce Hudson for analysis.

Reference to a company or product name does not imply approval or recommendation of the product by the U.S. Department of Agriculture to the exclusion of others that may be suitable.

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WASTE REDUCTION IN TABLE BEET PROCESSING

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P. H. Russell, Jr., P. E.**

Concern has been aroused throughout the canning industry on water pollution problems. Root vegetable crops, in particular, require relatively large volumes of water in processing operations, and substantial amounts of organic material are introduced into processing plant waste effluent. New York State is one of the largest producers of processed table beets in the United States, and more than 100 million gallons of wastewater and 20,000-30,000 tons of solid waste are released annually by beet processing plants.

At a conventional beet processing plant, fresh harvested beets received from the field pass through a screen to remove dirt and stones and then through a rod reel washer. The washed beets are graded and transferred to a steam or hot water blancher and carried through to a lye bath. Lye treated beets are fed into an expanded reel peeler to remove most of the peel and then finally passed through an abrasive peeler to clean all the surface including the crown. Peeled beets are then inspected on their way for dicing, filling, and processing.

The major source of pollution load in the processing of beets is the peeling operation. The waste effluent generated from conventional peeling is highly alkaline and contains considerable amounts of dissolved organic matters. This waste represents approximately 50% of the total plant effluent and more than 90% of the total plant solid waste (1).

In the conventional peeling operation of a typical beet processing plant (Figure 1), solid and liquid waste generated from the peeling line pass through a 20-mesh screen to remove the gross solids and then the liquid is pumped to a lagoon or delivered to a waste-disposal system. The gross solids are usually removed to a land fill. However, the very fine organic particles pass through the screen and contribute to the major waste water B.O.D. (Biochemical Oxygen Demand) and C.O.D. (Chemical Oxygen Demand) load.

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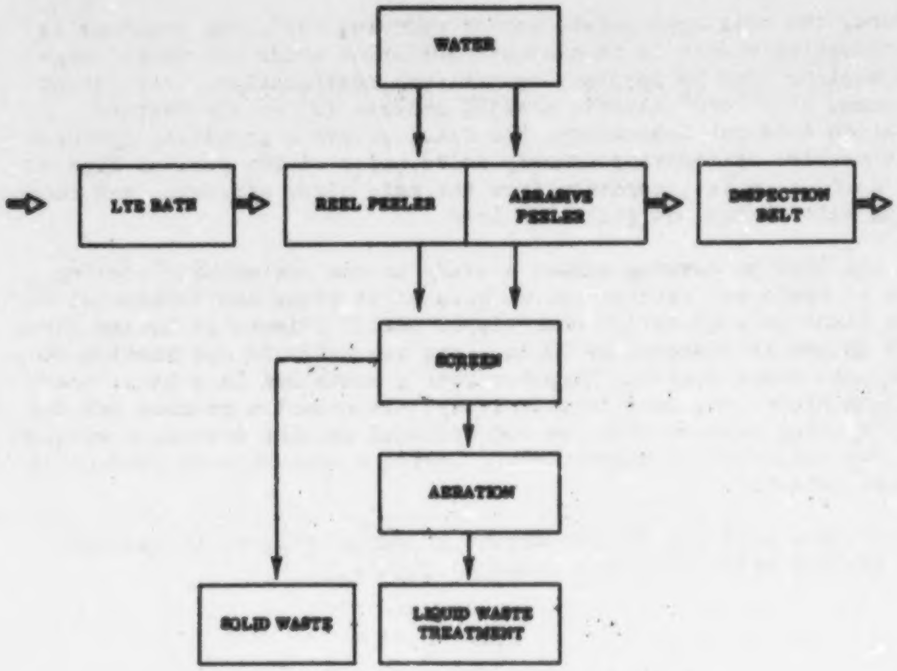
WATER
LYE BATH
REEL PEELER
ABRASIVE PEELER
INSPECTION BELT
SCREEN
AERATION
SOLID WASTE
LIQUID WASTE TREATMENT

Figure 1. Waste disposal practice in conventional beet processing plants.

Therefore, the most appropriate way of reducing pollution problems in beet processing plants is to minimize pollution loads and water usage in the peeling line by in-plant operational modification. The recent development of a "dry" caustic peeling process (2) at the Western Utilization Research Laboratory, U.S.D.A., offers a promising approach to this problem by removing cannery solid waste at the peeling line as a semi-solid material, separate from the main plant effluent, and consequently, reducing water usage and pollution load.

During the 1972 processing season a study on the dry caustic peeling process of beets was carried out on both pilot plant and commercial scales. A pilot plant unit of roll rubber-tipped peeler (Figure 2) having three rolls 8 inches in diameter by 38 in. long was built in our machine shop. A commercial scale peeler, "Magnuscrubber", installed in a local beet processing plant, was used in this study. In order to compare the dry caustic peeling process with the conventional peeling system, a similar survey was conducted in another plant having a conventional production line and equal capacity.

The water flow rate and the properties of waste effluent at two different peeling operations were compared (Table 1).

TABLE 1

WATER USAGE AND PROPERTIES OF EFFLUENT WASTE FLOW IN TWO DIFFERENT PEELING OPERATIONS OF BEETS

Measurement*	Conventional peeling	Dry caustic peeling
Raw beets input, ton/day	80	80
Water flow rate on peeling line, gal/day	48,000	12,000
Total solids, lb/day	10,200	1,050
Suspended solids, lb/day	340	40
C.O.D., lb/day	6,500	390
B.O.D., lb/day	2,670	190

* Average on 4 composite samples.

In processing 80 tons of fresh beets per day, the volume of water used in conventional peeling in both the tumble peeler and the abrasive peeler is around 48,000 gallons per day. When the tumble peeler is replaced with a scrubber, the water consumption volume is reduced to 12,000 gallons per day (75% reduction). Conventional peeling generated 10,200 lbs of total solids, while the dry caustic peeling produced only 1,050 lbs of total solids. Therefore, more than 85% of the total solid waste is collected and segregated from the main plant effluent. Suspended solids were reduced from 340 lbs to 40 lbs per day by the dry caustic peeling operation. The

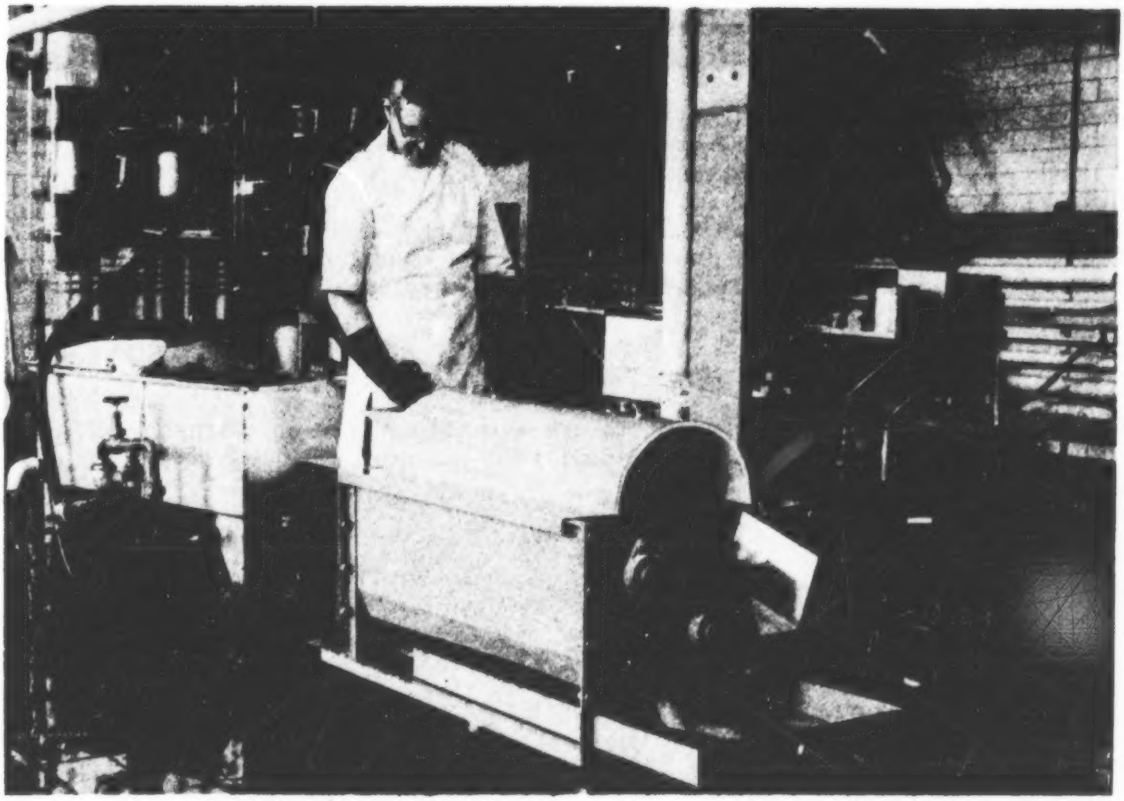

Figure 2. A pilot plant unit of roll rubber-tipped peeler built in machine shop of Food Research Laboratory was used for the dry caustic peeling process of beets.

dry caustic peeling operation affected more than 90% reduction in both C.O.D. and B.O.D.

In order to utilize the solid waste from the dry caustic peeling operation, exploratory work on animal feeding experiment was conducted. Solid wastes from the beet processing plant were collected in 30 lb tin cans. Air was introduced into the tin at room temperature to accelerate natural aerobic fermentation. After 5 days, the original pH of 11-12 was dropped to pH 6-7, and then fed to cows at a level of 4-5 lbs per day, either straight or as a 1:4 mixture with corn silage. Preliminary results with 4 cows showed that one cow was reluctant to eat and the other three cows were ready to eat. Seven to 10 days were required to adjust eating habits. It has been reported (3) that sodium hydroxide treatment of low quality roughages can increase digestibility by sufficient magnitude to improve animal performance. Therefore, the feeding of beet solid wastes with high sodium content appears promising.

In conclusion, it is clear that reduction of beet wastes from processing plants can be achieved by improved design and operation of processing machinery. The collected solid wastes can be utilized for animal feeding.

Acknowledgment

We thank Professor N. E. Smith, Animal Science Department, Cornell University for conducting the feeding studies.

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NEW METHODS UNDER INVESTIGATION FOR THE UTILIZATION OF FISH SOLUBLES, A FISHERY BYPRODUCT, AS A MEANS OF POLLUTION ABATEMENT*

by

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and Lee C. Schisler***

INTRODUCTION

The fisheries are faced with and will continue to be faced with the problem of sludge or solid waste disposal. As our technicians learn how to collect and handle waste solids and how to treat other waste effluents, methods must be found to dispose of the waste material. Materials that once went overboard or down the pipe will now be sludge or solid wastes that are potentially a further liability to the processor, but could represent additional assets if uses can be found for them. The name of this game is byproduct utilization and its origin dates back to the pre-history of man.

There are various suggested methods for the proper disposal of solid or sludge wastes such as landfill, incineration, pyrolysis, composting, and dumping at sea, most of which, with the exception of the latter, may not be too practical to coastal-based fisheries because they require land or create additional problems. Dumping at sea is currently under investigation, however State and Federal Legislation has been passed forbidding dumping within our territorial seas.

In the published report entitled, "Current Practices in Seafoods Processing Waste Treatment," Soderquist et al. (19) proposed various disposal methods, including dumping at sea, as the means of pollution abatement. This practice might currently apply to Alaska and the Northwest where high shipping costs would discourage transport of recycled materials.

We propose that most fishery wastes could be recycled through proper utilization and thus conserve some of our natural resources as well as help relieve some of the cost of pollution abatement. Animal feeding is one obvious answer and the fisheries have the know-how and technology that could be adapted to fishery sludge and solid wastes. However, in some

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* Funded by the U.S. Department of Commerce, NOAA, NMFS.

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of these wastes, the protein is of poor quality or in low quantity and the fat content may be high--not always advantageous for some feeds, like poultry feed. Our approach is to seek new potential markets where the properties of the byproduct might be desired and where some of the apparent disadvantages might even be advantageous.

For our initial investigations we chose menhaden fish solubles for several reasons: it is an established byproduct; its processing technology which is condensing the waste effluent called "stickwater" is well known; it is stable under acidified storage conditions; its market competes with fish meal in poultry feeding; more fish solubles are now being produced in line with pollution abatement and the market is not improving (more supply than demand); and some other waste effluents in the future may also be acidified and condensed and thus resemble fish solubles. Hence we felt we could do the most good initially by investigating fish solubles and paving the way for other condensed waste effluents by our experiences and expertise gained on these projects.

UTILIZATION OF FISHERY BYPRODUCTS IN MUSHROOM CULTURE

One of our first approaches to utilizing fish solubles was to consider producing mushrooms, a higher form of fungi (basidiomycetes), by submerged culture techniques. We soon found out from background information and the advice of Drs. James San Antonio and Claude Fordyce of the U.S. Department of Agriculture Mushroom Research Center at Beltsville, Maryland, that submerged mushroom culture was only in experimental stages. However, we learned from the same sources and from pamphlets that there was a need for organic nitrogen supplements for mushroom composts (8,15).

In making composts from either straw bedded horse manure or corncobs and hay (synthetic), the mushroom grower has found that he must increase the nitrogen content. To do this he adds organic nitrogen in the form of chicken manure, cocoa bean hulls, cottonseed meal, or brewer's grain; the latter is currently preferred today, but has become expensive. Chicken manure varies in its nitrogen content from 2-6% and presents problems to the mushroom grower in terms of consistency, proper mixing, and occasional excess ammonia formation during composting. Excess ammonia will kill mushroom growth during spawning (seeding). Inorganic nitrogen or small organic molecules, such as urea, are usually less expensive but they leach out of the compost pile during watering of composts. In addition, inorganic nitrogen does not give results as good as those of organic nitrogen, hence the desire for organic nitrogen substances by the mushroom growers. Their supplies of desired nitrogen supplements are getting to be more expensive as the demand for these materials increases. There are companies that supply mushroom growers with a mixture of dried organic nitrogen substances of guaranteed consistency of nitrogen content.

The nitrogen supplement does not directly supply nutrients to the mushroom. They are important in the compost process which must go on prior to spawning with mushroom. The composting is carried on by a variety of microorganisms, including thermophilic bacteria, actinomycetes, and fungi (2). Good growth of these composting microorganisms yields a biologically stable compost for mushrooms which are really slow-growing fungi. A variety of microbial growth also continues in the compost during mushroom growth and production (3). Poor composting produces poor or no yields of mushrooms, hence the compost ingredients are very important in order to get good microbial aerobic growth. The large compost piles are routinely turned for aeration and watered to supply moisture for microbial growth. Temperatures get as high as 160-180°F. Mushrooms are grown in beds or trays inside houses for a period of about 4 months until the yields from spent compost become low, then the beds or trays are cleaned out, replaced with new compost, and the spawning/mushroom growing cycle is repeated.

Approximately 2,300,000 tons of mushroom compost were produced in the United States in 1972 and would require the equivalent of approximately 140,000 tons of fish solubles at 5% nitrogen content for supplementation. Mushroom production in the United States increases each year by about 6-8%. About 61% of the U.S. production is grown in Pennsylvania, primarily in the southeastern area; about 9% in California; and the rest scattered in other states, primarily New York, New Jersey, Delaware, Maryland, Oregon, and Michigan (21). The Pennsylvania area would be close to our mid-Atlantic fisheries. California and Oregon could be served by the West Coast fisheries and the Great Lakes fisheries could supply the Michigan area.

Fish solubles would be well suited for nitrogen supplementation in mushroom compost. The characteristics of fish solubles have been described by Soares et al. (18). The nitrogen content is consistent for the many samples tested, approximately 5.1 ± 0.4%, and it is primarily organic nitrogen. It is a liquid slurry, which could be diluted with water and applied during the initial stages of composting when the compost materials are periodically watered down. The residual fish oil in solubles may be important in enhancing mushroom production, and we are now aware from other evidence to be described here later that fish solubles support good microbial growth. We need to experimentally show that menhaden fish solubles could feasibly support good mushroom composting and produce mushroom yields equivalent to other nitrogen supplements currently in use.

A contract was made with Dr. Lee C. Schisler of the Mushroom Research Center at the Pennsylvania State University to explore the use of menhaden fish solubles in mushroom culture. He substituted fish solubles for the two nitrogen supplements routinely used at this experimental facility: dried brewer's grain (about 4% nitrogen) and Acto 88, a commercially available dried nitrogen supplement preparation which contains 8.8% nitrogen.

Two strains of mushrooms were used: a white or "fresh market" strain and a faster growing cream or "canners" strain. Four experimental composts were prepared: a control compost supplemented with a 50:50 mixture, based on nitrogen content, of brewer's grain and Acto 88; the other three composts had fish solubles substituted for one or the other or both of these nitrogen supplements.

Table 1 shows the general results from Dr. Schisler's experiment. Note that when fish solubles is substituted for Acto 88 (#3 compost), the yields are equal. When substituted for brewer's grain (#2 and #4 composts), the yields are apt to be less. Brewer's grain is the best of the nitrogen supplements. Acto 88 is also considered by growers to be a very good supplement.

Table 1. Relative yields of mushrooms grown on horse manure-straw-gypsum mixture compost containing fish solubles as nitrogen supplement and compared to control.

Nitrogen supplement[a]	White strain[b]	Cream strain[c]
1. Brewer's grains Acto 88	Control	Control
2. Fish solubles Acto 88	Less*	Less*
3. Brewer's grains Fish solubles	Equal	Equal
4. Fish solubles	Equal	Less*

* Very significant differences ($P \leq 0.01$).

[a] Nitrogen supplements were added so that each supplement contributed 50% of the N. The total N in all composts is the same.

[b] White strains are used for fresh market mushrooms in the Eastern states.

[c] Cream strains usually grow faster, yields are greater, and they are used for commercial canning.

Another interesting aspect, fish solubles combined with brewer's grain (#3 compost) in both strains, or with Acto 88 (#2 compost) for the white strain produces significantly larger mushrooms (Table 2). This is important to the grower because costly hand picking is still employed; larger mushrooms mean less picking time per yield and bring a better price. These experiments have shown that fish solubles can be successfully used in mushroom compost. There are more considerations which should be investigated. It will be a while yet before the mushroom grower is convinced to try it.

Meanwhile we have another interesting venture in the mushroom industry. Dr. Schisler has previously shown the mushroom growers that small quantities of polyunsaturated vegetable oils, such as cottonseed or soybean, in the compost could stimulate an increase in mushroom yields by 15-20% (13, 14). The polyunsaturated lipids may be enhancing the growth of thermophilic microorganisms--a speculation based on information found in the literature. We have continued our contract with Dr. Schisler to investigate the use of fish oils, which are more polyunsaturated than vegetable oils, as a stimulant for increased mushroom yield. Besides a potential market for menhaden oil, this could also lead to methods by which to utilize fishery wastes with high polyunsaturated oil residues. There are several areas in mushroom culture currently under investigation by Dr. Schisler and others where combinations of oil and/or organic nitrogen could be used (13, 14). There are several potential fishery wastes that could qualify.

PEPTONES FROM FISHERY PRODUCTS AND BYPRODUCTS

Our second major approach to fish soluble utilization was again through the eyes of microbiologists. The amino acid profile of fish solubles (18) indicates the presence of all amino acids; however, there is not an abundance of all essential amino acids required by monogastric animals. Also part of the nitrogen is present in the form of non-protein nitrogen. Microbes are "animals" (little beasties of Leeuwenhoek). Why not feed them a mixture of all amino acids and non-protein nitrogen on both of which microbes can easily survive and grow? Why not make fish solubles into a "peptone" for microbiological media? We proceeded to do so (4, 5). The microbiologist requires that his peptones be clear in solution and non-heat coagulable, also to be void of metabolizable energy sources such as carbohydrates and lipids (these are added to culture media per formulation requirements). We soon devised a method of defatting fish solubles with hexane and removing the particulate matter via centrifugation. The clear, fat-free supernatant fluid remaining was primarily non-heat coagulable proteinaceous material plus residual acids and mineral salts. This material, which we called soluble fish extract (SFE), was freeze dried and used as a peptone in simple microbiological media. We also explored some fish hydrolysates that were developed by Malcolm Hale of our facility as part of our fish protein concentrate (FPC) program (6). We called one a soluble hake autolysate (SHA). Hydrolysates could perhaps be produced from solid fishery wastes, such as heads, tails, and other trimmings.

Table 2. Relative size of mushrooms grown on horse manure-straw-gypsum mixture compost containing fish solubles as nitrogen supplement and compared to control.

Nitrogen supplement[a]	White strain[b]	Cream strain[c]
1. Brewer's grains Acto 88	Control	Control
2. Fish solubles Acto 88	Larger*	Equal
3. Brewer's grains Fish solubles	Larger*	Larger*
4. Fish solubles	Equal	Equal

* Very significant differences ($P \leq 0.01$).

[a] Nitrogen supplements were added so that each supplement contributed 50% of the N. The total N in all composts is the same.

[b] White strains are used for fresh market mushrooms in the Eastern states.

[c] Cream strains usually grow faster, yields are greater, and they are used for commercial canning.

Table 3. Proximate analysis for SFE and SHA

Material	Protein	Moisture	Ash	Fat	Total
SFE	60.35	5.16	32.93	0.38	98.8
SHA	79.71	3.79	13.61	0.40	97.5

Table 3 shows the proximate analysis of SFE and SHA. Both are low in fat. The high ash content of SFE is due to the original high acid concentration which has been neutralized with dilute NaOH. It might be possible to improve this analysis by starting with unacidified stickwater, the waste effluent from the cooking and pressing processes used in making fish meal.

Table 4 shows both the total and free amino acids contents of SFE and SHA. The lower percent of total amino acids, over crude protein in SFE, would indicate that probably some of the nitrogen is non-amino acid nitrogen, which is also desirable for microbial growth. Some species thrive on non-protein nitrogen or inorganic nitrogen. We have the proper nitrogen nutrients in here for most every species of the microbial world.

We compared our fish peptones to other commercially available peptones derived by hydrolysis of casein, meat, or soya. We did this comparison by specific species growth in simple broth cultures and noted turbidity. Figure 1 shows a typical growth curve for Pseudomonas aeruginosa-- the SFE is leading the commercial peptone. Beef extract is another type of commercially available material used in microbiological media (4).

Another way in which we compared fish peptones with other peptones was to prepare simple agar media--also standard agar media formulations-- and to compare the recovery of specific species or mixed populations using the standard media as referenced. Table 5 shows typical results for the recovery of mixed populations of microbes found in water, milk, soil, and hamburger (5).

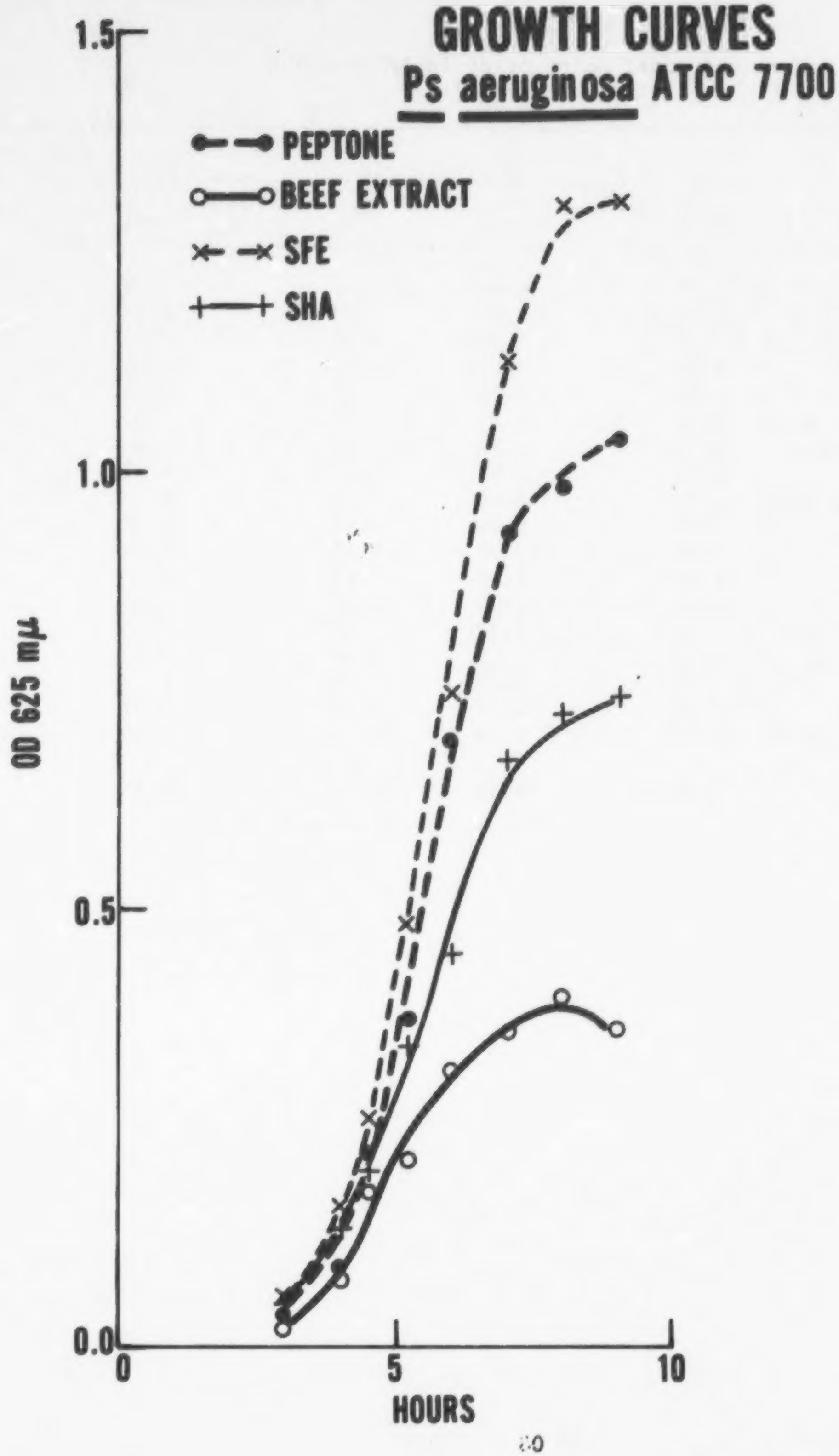
This is our initial endeavor in this research to show that fish peptones either derived from waste effluents or produced as fish hydrolysates, can support microbial growth and compete in this market. Currently suitable hydrolysates of casein or meat sell for about $2.00 or more per pound. We envision use of fish peptones in industrial microbial processing, such as antibiotic or enzyme production. They might eventually be used in laboratory or clinical media. However, laboratory microbiologists have stringent requirements for the types of peptone used in their research laboratory or clinical media. They also resent change from peptones that they have become familiar with over the years. Who knows, perhaps fish peptones might enhance the growth of some or many microbes. We have by no means explored all aspects of the use of fish peptones in microbiological media. Our contribution, however, is that the clear, defatted fishery byproduct, such as fish solubles, might serve this purpose. Hence the reason for our investigation--a new utilization for fish solubles and perhaps other fishery wastes.

These two approaches, mushrooms and media, have been our main theme for the past 1-1/2 to 2 years. However, we have other approaches under consideration for the possible utilization of fish solubles or other fishery wastes. Two of these are as follows:

Table 4. Free and total amino acids in SFE and SHA

Amino acid	% of protein			
	SFE		SHA	
	Free	Total	Free	Total
Lysine	1.14	4.64	1.60	8.55
Histidine	1.58	3.03	--	1.55
Ammonia	1.33	3.33	0.17	1.57
Arginine	0.20	3.93	--	6.04
Taurine	3.96	4.60	1.23	1.34
Aspartic acid	0.56	4.50	0.39	10.05
Threonine	0.32	1.85	0.48	4.20
Serine	0.25	2.02	0.45	4.19
Glutamic acid	0.42	7.74	0.76	16.88
Proline	0.37	5.64	0.15	5.79
Glycine	0.68	12.39	0.29	8.49
Alanine	1.60	6.50	0.91	7.01
Valine	0.55	2.09	0.69	4.26
Methionine	0.23	1.37	0.44	2.73
Isoleucine	0.39	1.17	0.48	3.37
Leucine	0.79	2.63	1.33	6.71
Tyrosine	0.24	2.75	0.50	0.99
Phenylalanine	0.43	1.56	0.78	2.84
Total	15.04	69.74	10.93	96.56

FIGURE 1



GROWTH CURVES

Ps aeruginosa ATCC 7700

Table 5. Recovery of microorganisms from water, milk, soil, and hamburger using various media.

Material		Agar media					
		SMA (Standard)	Nutrient Agar	Peptone	Beef Extract	SFE	SHA
Water	X10^4	5.77	4.82	5.55	1.97**	7.33	7.91
Milk	X10^3	6.15	4.13**	3.47**	7.52	3.60**	3.58**
Soil	X10^7	1.20	.90*	1.28	.97	.97	1.20
Hamburger	X10^7	7.85	7.00	3.77**	4.65**	6.17**	5.22*

* Significant difference from standard.

** Very significant.

ANIMAL FEEDS: DIRECT AND IN COMBINATION WITH OTHER BYPRODUCTS

One approach under consideration is the use of fish solubles as an inexpensive protein source in ruminant diets. Dr. W. M. Beeson's Animal Nutrition Group at Purdue University has been exploring the efficiency of adding various inexpensive protein-containing substances as a "rumen" "stimulatory factor" or "urea supplement" in high-urea diets to increase urea utilization in cattle (22). For this purpose he has employed corn distiller's dried solubles, fish solubles, and dehydrated alfalfa meal. These protein-containing substances added to high-urea diets stimulate the rumen microbes to better protein synthesis, hence better utilization of the total nitrogen in the diet. Again, in ruminants, we are feeding microbes. Dr. Beeson's one research on fish solubles has been only partially satisfactory, but not conclusive that fish solubles would work as well as corn distiller's dried grains or dehydrated alfalfa meal. Our facility's animal nutrition group has initiated a project to explore the use of fish solubles in ruminant diets.

If fish solubles can be economically used as a rumen stimulatory factor in ruminant diets, then a new market could exist that would not compete in the poultry feeding industry. The market would be very extensive and located near many of our fisheries.

Another approach takes a similar consideration, that is ruminant feeds, but with an interesting multi-utilization, which would be to combine acidified fish solubles with caustic agronomic wastes. The U.S. Department of Agriculture and other concerns have developed a "dry" caustic peeling method for potatoes that is now being applied to other root-type vegetables and some tree fruits. Reports of these studies have been previously made in 1971 and 1972 at this Conference (1, 11, 17). This new method removes the peel as a thick sludge which can be separately channeled off from the processing line. As many of you at this Conference already know, there are many advantages in both pollution control and processing efficiency to this new "dry" method which will probably soon be adapted by most of the potato industry. The potato peel sludge is about 12-15% solids but has a high pH of about 12. Various animal nutritionists, such as Dr. Wilton W. Heinemann of the Washington Agricultural Experiment Station, Prosser, Washington, have shown that this material mixed with hay and other ingredients can be fed to cattle (7). However, in order to reduce the high pH to near neutrality, it is necessary to allow the caustic potato peel to stand in troughs or ditches for about 2 weeks or more. Probably some naturally occurring microbial populations reduce this pH. Possibly a "pancake-batter" effect in which a natural inoculum gets established and continues to act as new potato peel sludge is added. This is speculation since there is apparently no information as to why the pH drops in the slurry while standing in troughs or ditches.

Instead of waiting 2 weeks or more, caustic potato slurry could be neutralized immediately by the addition of acidified fish solubles or acidified fish solubles and phosphoric acid. The objective would be to neutralize the two byproducts for immediate use: to increase the ionic strength needed in ruminant diets; and to add protein and fat to a carbohydrate material for an improved diet.

Figure 2 shows titration curves of the pH reduction in two caustic samples of potato slurry by the addition of acidified fish solubles. There is little buffer capacity in the potato slurry waste, largely carbohydrate and inorganic materials. About 15-20% fish solubles would bring the slurry into edible pH range. Figure 3 shows similar curves for two samples of caustic sweet potato peel.

Figure 4 shows a similar curve for one sample of caustic beet peel waste and another sample of Irish potato peel waste. In experiments illustrated by Figures 3 and 4, two different samples of fish solubles were used. One sample, B, is apparently more acid than sample A. Also, the sweet potato sample, JA (Figure 2) was apparently more caustic than the other potato samples and initially resisted reduction in pH. Future use of these combined wastes would have to observe pH changes and might have to make some processing adjustments to reduce excess caustic effect.

At this time not all potato processors have installed this equipment. However, it is exptected that in 5-6 years most potato processors and many other vegetable or fruit processors will have done so. The method is a great advancement in pollution abatement for these industries. Data from the U.S. Department of Agriculture dated 1958-64 (8) indicate that 55% of all potato production occurs in the 22 coastal states of mainland United States (does not include Alaska or Hawaii). The U.S.D.A. figures for 1971 (20) show that over one-half of the U.S. potato production is processed into fried, chips, canned, or frozen potatoes which means that most of them will have to be peeled.

Table 6 indicates some of the amounts of potatoes processed (10, 20) and an estimated amount of dry caustic potato peel from Irish potatoes. Considering that over one-half of this production is in coastal states, it could represent a potential outlet for acidified fishery wastes.

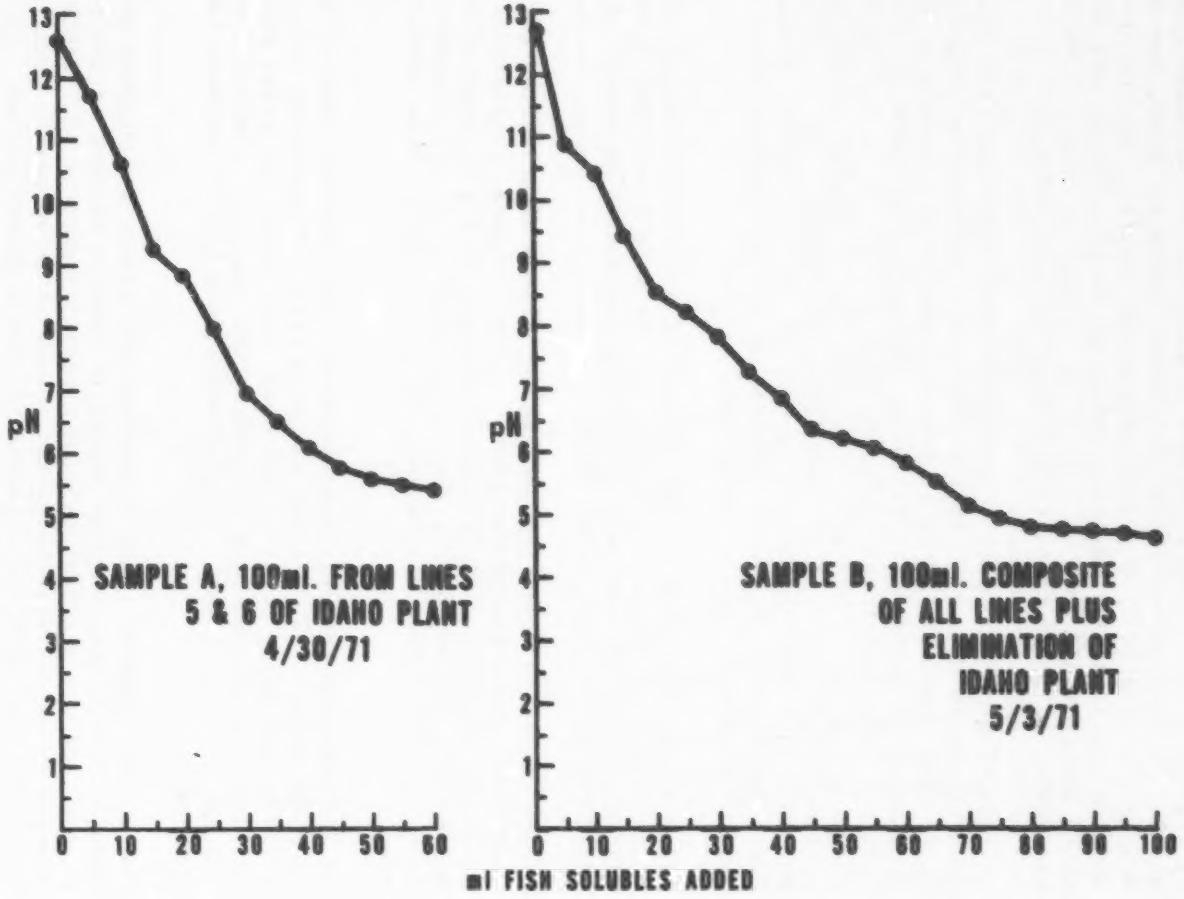
We are currently exploring wet and dry blends of acidified fish solubles mixed with these agronomic wastes. In wet blends, characteristics are noted and possible microbiological changes during storage of 2-4 weeks. Hydroscopic properties are also being examined in dry blends with the concept that dried feed supplements could be prepared from these blended by-products.

We did some very simple experiments to determine the keeping qualities of these blends. We blended 15% acidified fish solubles with 85% caustic Irish potato peel, sweet potato peel, beet peel, and peach peel wastes, measured the pH, and took microbiolgical samples for about 3 weeks' storage in clean plastic covered containers kept at ambient laboratory temperatures.

The microbiology of these substances and blends was studied periodically. Among other things, we were hoping to observe changes in the potato peel blends that would correlate with a possible drop in pH. Table 7 shows changes in pH and microbiolgical counts of Irish potato peel, peach peel, and fish solubles experiments over a 3-week period. In Irish potato peel, no detectable microbes were observed and pH slowly dropped from 12.2 to 10.7, possibly by loss of ammonia. The caustic peach peel went wild with microbial growth, mostly yeast and molds--it reached a

FIGURE 2

TITRATION CURVES: FISH SOLUBLES (pH 4.4) ADDED TO 'DRY' CAUSTIC POTATO PEEL WASTE



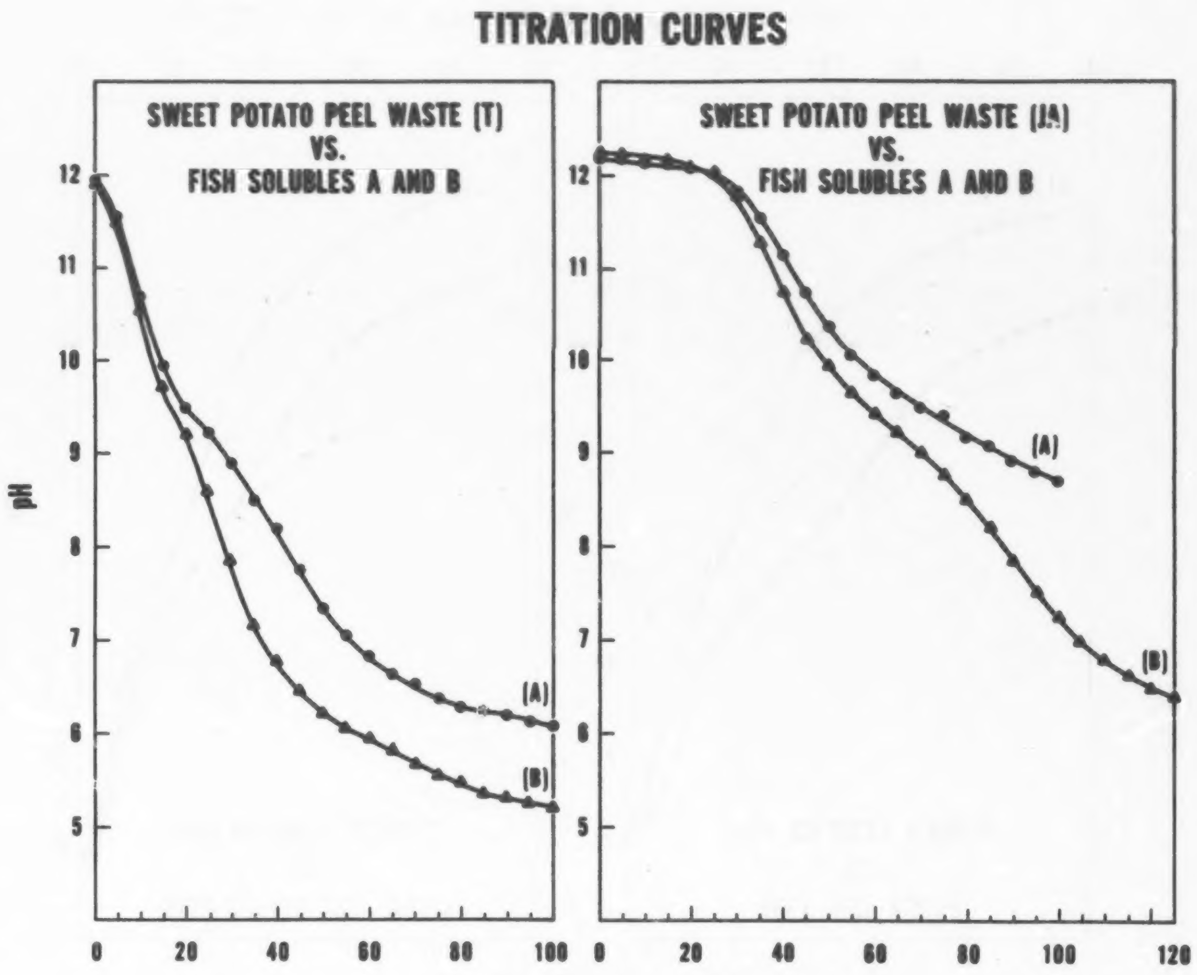

TITRATION CURVES
SWEET POTATO PEEL WASTE (T)
VS.
FISH SOLUBLES A AND B
SWEET POTATO PEEL WASTE (JA)
VS.
FISH SOLUBLES A AND B
pH
12
11
10
9
8
7
6
5
(A)
(B)
0
20
40
60
80
100
120
ML FISH SOLUBLES ADDED TO 100ML OF PEEL WASTE

Figure 3

TITRATION CURVES

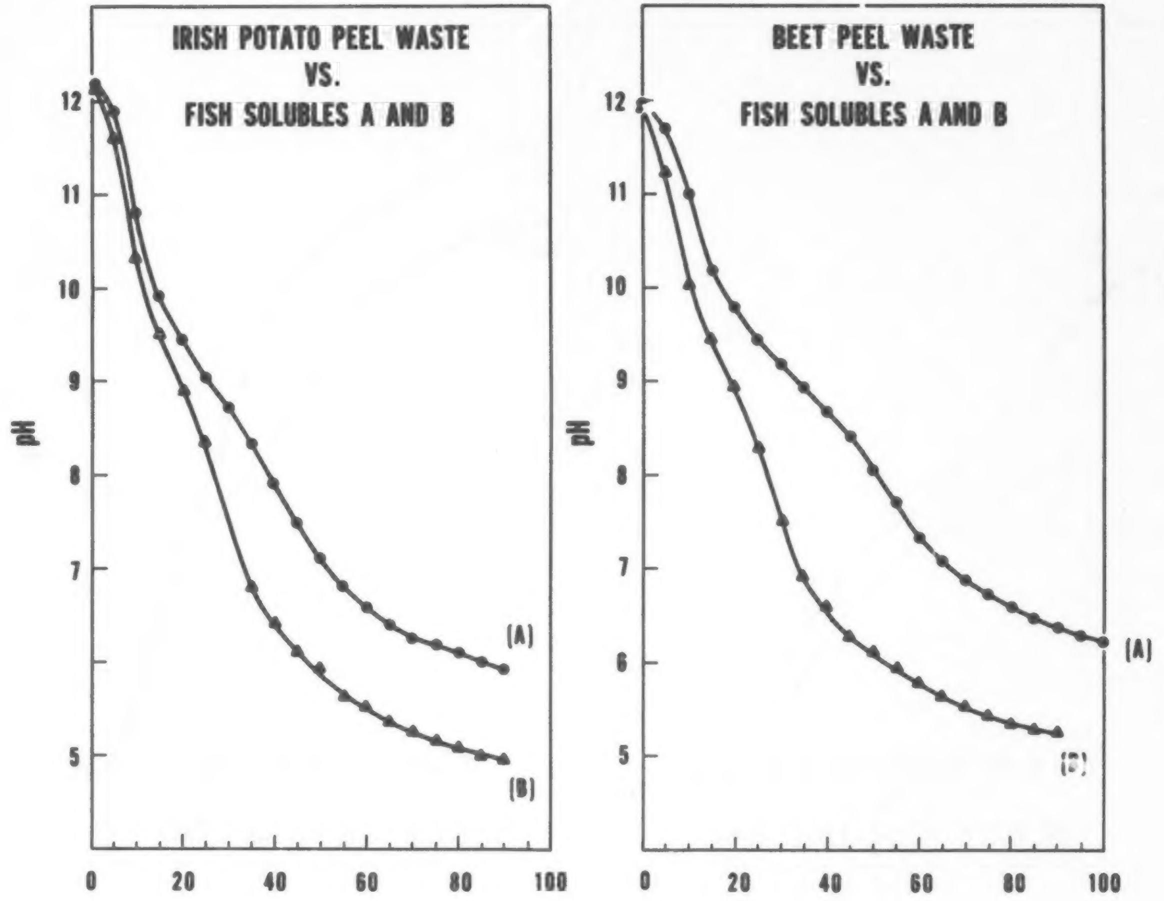


Figure 4. ML. FISH SOLUBLES ADDED TO 100 ML OF PEEL WASTE

Table 6. Average annual potato waste from processing operations in the the United States. Various yearly averages [a,b].

Potato	Process	Tons[c]/year potatoes processed	Tons[c]/year potato waste
Sweet potato[a]	Canning	151,200	45,965
Irish potato[a]	Canning	83,833	27,262
Irish potato[b]	Peeled for fries, chips, canning, etc.	6,915,000	350,000 (est)[d]

[a] 1968-1970 period, annual averages. Data supplied by National Canners Association, Washington, D.C. 20036.

[b] 1971 Irish potatoes. Utilization of 1971 crop. Statistical Reporting Service, Crop Reporting Board, USDA, Washington, D.C. 20250. Bulletin Pot - 1-3 (9-72).

[c] Thousand cwt or case numbers converted to short ton figures.

[d] Estimated loss based only on 5-6% fresh potato loss during "dry" caustic potato peeling process. Further losses from other food processing not accounted for.

Table 7. Changes occurring in peel waste slurries or fish solubles and in blends of peel waste/fish solubles during 21 days' storage at room temperature[a]

Material	Criteria Measured	Days of incubation 0	3	6	11	14	21
Potato Peel Waste	TPC[b]	<300[d]	<300	<300	<300	1.5×10^{4}	<300
	YMC[c]	<300	<300	<300	<300	2.3×10^{2}	<300
	pH	12.2	12.2	12.2	11.8	11.1	10.7
Peach Peel Waste	TPC	1.5×10^{8}	7.8×10^{8}	1.24×10^{9}	5.4×10^{9}	2.6×10^{9}	2.72×10^{9}
	YMC	2.6×10^{4}	3.7×10^{7}	1.2×10^{6}	9.0×10^{7}	1.4×10^{8}	2.4×10^{8}
	pH	8.1	4.6	5.1	5.7	5.5	9.9
Fish Solubles	TPC	1.3×10^{4}	2.0×10^{4}	1.3×10^{4}	1.1×10^{4}	1.3×10^{4}	1.1×10^{4}
	YMC	<300	<300	<300	<300	<300	<300
	pH	4.7	5.0	5.2	5.3	5.7	5.6
Potato Peel (85%) and Fish Solubles (15%)	TPC	2.6×10^{3}	2.0×10^{4}	3.6×10^{3}	1.0×10^{5}	5.6×10^{6}	2.4×10^{10}
	YMC	4.2×10^{2}	1.2×10^{4}	<300	<300	<300	<300
	pH	9.7	9.2	9.7	9.5	9.2	7.9
Peach Peel (85%) and Fish Solubles (15%)	TPC	7.5×10^{7}	2.0×10^{10}	7.0×10^{6}	1.1×10^{9}	5.2×10^{8}	1.4×10^{8}
	YMC	1.5×10^{4}	1.0×10^{6}	$<3 \times 10^{6}$	$<3 \times 10^{4}$	$<3 \times 10^{3}$	<300
	pH	4.9	4.0	4.7	5.6	4.7	4.7

a. Room temperature averaged in the 22-26° C range.
b. Total plate counts were determined using SMA, 37° incubation.
c. Yeast-mold counts were determined using PD agar at pH 5.5, 25° incubation.
d. Reported estimate based on less than 30 colonies on agar petri plates of the lowest dilution. In most cases one-tenth was the lowest dilution.

peak in about 11 days; the pH dropped from 8.1 to 4.5 then rose again to 10.1. We have suggested to the peach processor that caustic peach peel could perhaps be boiled down and used as a molasses in feed mixes; it has a sweet aroma and appears to make a nice texture when blended with other slurries. We have also suggested, half seriously, that it might be an excellent starting material for a peach brandy.

The caustic Irish potato peel and fish colubles made very few changes for the first week, then the microbe population increased and the pH began to decline toward neutral. Fish solubles show no changes during the 3 weeks; it is known to remain very stable for long periods of time. The low pH, high ionic strength, and high osmotic concentration probably discourage most microbial growth.

On another occasion, blends were prepared of acidified fish solubles and caustic Irish potato, sweet potato from two different sources, and beet peel wastes. Table 8 shows the results of storage of these blends. They all appear to be stable for the 17 days depicted. The same experimental samples tested at 27 days (data not shown) still show no changes.

Some samples of experimental sheep feeds and a liquid supplement premix made of fish solubles, caustic potato peel, molasses, some urea, and phosphoric acid were examined for microbial and pH changes. Figure 5 shows the results of storage of these blends. Both the control feed containing a molasses, urea, phosphoric acid premix and the experimental feed containing a potato waste/fish solubles, etc., premix showed rapid microbial growth. The experimental diet was quicker to reach a peak and in practice it developed a musty odor quicker than the control feeds. The premix itself rapidly grew a single species of bacteria, that appeared to be a micrococcus, and then lost it viable count. The pH changes of this study are shown in Figure 6. These feeds used in experimental studies were well mixed. In practice, liquid feed supplements are added on top of corn/alfalfa, etc., meals. Our experiments on hydroscopic properties of blends of Irish potato peel and fish solubles met with some technical difficulties. They are being repeated. We have not explored dried caustic sweet potato or beet peel wastes and fish solubles blends as yet. I have been informed that sweet potato is hydroscopic. We know that dried fish solubles is very hydroscopic--one of the reasons it is seldom dried and stored alone. We plan to investigate these dried blends for the purpose of seeing if dried preparations would keep reasonably well.

SUMMARY

In summary, we have been considering various new ways to utilize acidified fish solubles. Our microbiolgically oriented backgrounds have gravitated towards thinking microbes, such as mushrooms, media, and even ruminant microbiology. Where the byproducts' characteristics appeared to be a disadvantage in one situation, they sometimes turned out to be desired characteristics in another. At the moment, none of these approaches has hit pay dirt although there are a few nibbles on the line. Results look promising, reports have been made to interested parties, and publications are being prepared or are in press. It will be a while before new markets for byproducts are developed. We hope they can be developed and that they will be substantial to absorb fish solubles or similar fishery byproducts.

Table 8. Changes occurring in peel waste slurries, fish solubles and blends of peel waste/fish solubles during 17 days of storage at room temperature[a].

Material(s)	Characteristic measured	Days of Incubation 0	2	4	7	12	17
Irish pot. peel waste (C)	TPC[b]	<300[d]	<300	<300	<300	<300	<300
	YMC[c]	<300	<300	<300	<300	<300	<300
	pH	12.3	11.9	12.0	11.6	---	11.8
Sweet pot. peel waste (T)	TPC	<300	<300	<300	<300	<300	<300
	YMC	<300	<300	<300	<300	<300	<300
	pH	12.2	11.8	11.9	11.5	---	11.6
Sweet pot. peel waste (JA)	TPC	<300	<300	<300	<300	<300	<300
	YMC	<300	<300	<300	<300	<300	<300
	pH	12.1	11.6	11.8	11.4	---	11.4
Beet peel waste (L)	TPC	<300	<300	<300	<300	<300	<300
	YMC	<300	<300	<300	<300	<300	<300
	pH	12.4	11.7	11.9	11.6	---	11.6
Fish solubles A (H)	TPC	$3.0\text{x}10^3$	$2.3\text{x}10^3$	$2.6\text{x}10^3$	300	$5\text{x}10^3$	$1\text{x}10^4$
	YMC	<300	<300	<300	<300	<300	$1.5\text{x}10^3$
	pH	4.8	4.7	4.5	4.5	---	4.4
Irish pot. 85% solubles 15% (CH)	TPC	$4\text{x}10^3$	<300	<300	<300	<300	$1.7\text{x}10^3$
	YMC	<300	<300	<300	<300	<300	$1.5\text{x}10^3$
	pH	10.2	9.8	9.8	9.7	---	9.4
Sweet pot. 85% solubles 15% (TH)	TPC	<300	<300	<300	<300	<300	<300
	YMC	<300	<300	<300	<300	<300	<300
	pH	10.9	10.6	10.6	10.4	---	9.8
Sweet pot. 85% solubles 15% (JAH)	TPC	<300	<300	<300	<300	<300	<300
	YMC	<300	<300	<300	<300	<300	<300
	pH	12.0	11.9	12.0	11.9	---	11.7
Beet peel 85% solubles 15% (LH)	TPC	<300	<300	<300	<300	<300	<300
	YMC	<300	<300	<300	<300	<300	<300
	pH	10.7	11.0	11.1	10.9	---	10.5

a. Room temperature averaged in the 22-26°C range.
b. Total plate counts were determined using SMA, 37 incubation.
c. Yeast-mold counts were determined using PD agar at pH 5.5, 25° incubation.
c. Reported estimate based on less than 30 colonies on agar petri plates of the lowest dilution. In most cases one-tenth was the lowest dilution.

FIGURE 5

TOTAL AND YEAST/MOLD COUNTS DURING STORAGE OF FEEDS AND A PREMIX

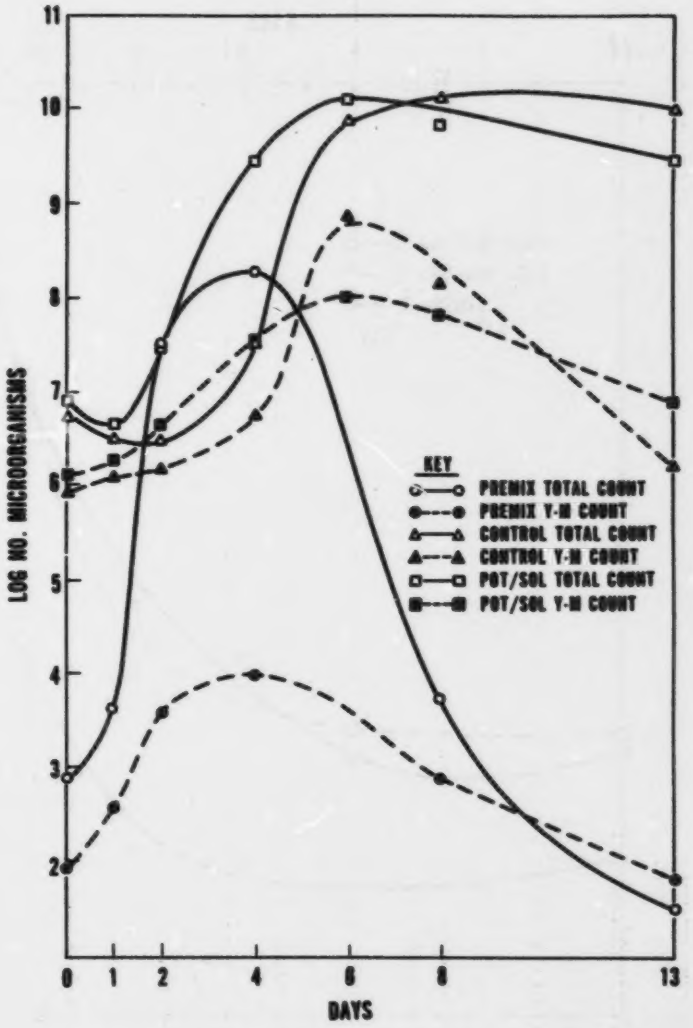
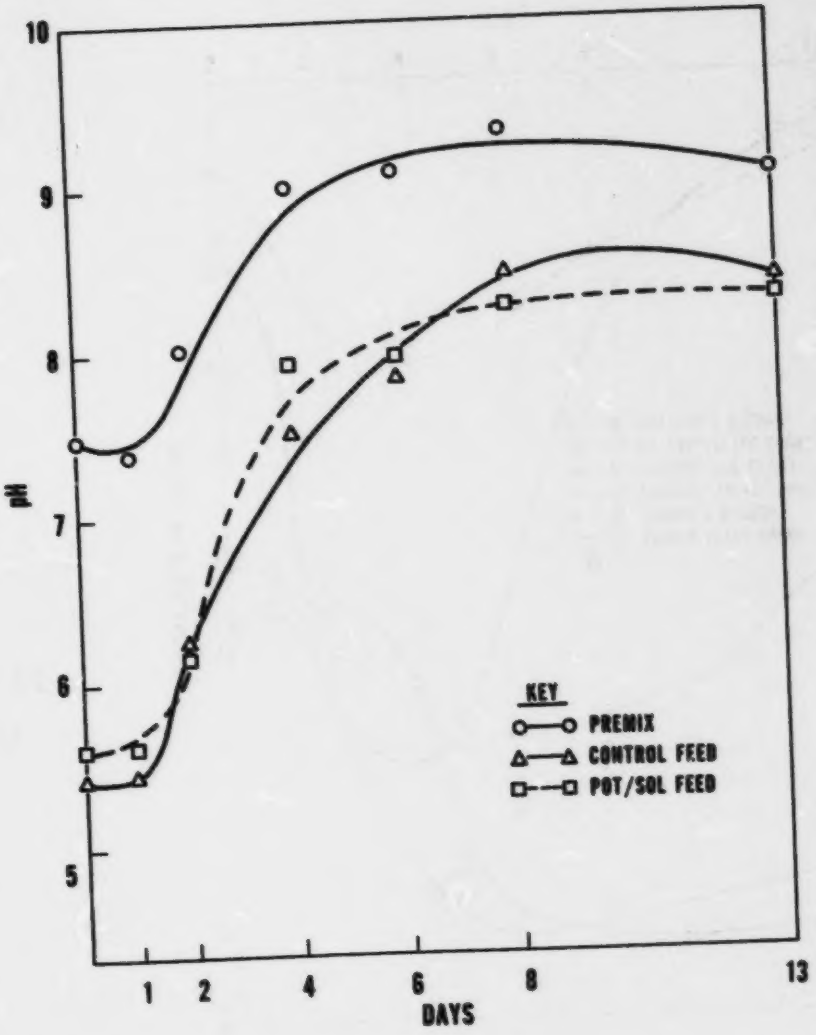


FIGURE 6

pH CHANGES DURING STORAGE OF FEEDS AND A PREMIX



Of the first two approaches cited, utilization in mushroom culture could absorb vast quantities of fish solubles. The normal market price for fish solubles could readily compete with the market prices of nitrogen supplements now available to the mushroom grower. In addition, the proximity of many coastal and Great Lakes fisheries to mushroom growing areas makes this application look promising. Peptones for microbiological media are now being experimentally produced from both fishery byproducts and from fish by at least one company. This could represent an inexpensive supply of peptones for both commercial and clinical use. It could also represent a lucrative way of utilizing proteinaceous byproducts of the fisheries or other food processors.

The other approaches cited are still under investigation. The efficiency and the economic value of feeding ruminants with byproducts is being carefully considered by the animal nutritionists. Again the proximity of coastal and Great Lakes fisheries to many animal-feeding areas gives this approach an advantage. Should blending of acidified fishery wastes with caustic peel wastes be economically feasible, there are many coastal areas where proximity between these sources might make some byproduct marriages possible.

Although acidified menhaden fish solubles was our main byproduct for this investigation, we are keenly aware that other byproducts exist now or will exist in the future to be explored for utilization. We hope that these investigations described here will pave the way for other fishery byproduct utilization. We also hope that other industries may benefit by these described examples.

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EXCHANGE PROPERTIES OF A SOIL USED FOR THE DISPOSAL OF ALKALI CANNERY WASTES

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Land disposal of wastewater from canneries on well-drained permeable soils is a popular means of disposal. This practice has several advantages: (1) most organics are oxidized to innocuous compounds, (2) significant amounts of nitrogen in the ammonium and organic forms are oxidized to nitrates and absorbed by soil cover crop and (3) soil fixation of phosphorus has been well documented.

In processing table beets sodium hydroxide is used to remove the outer skins. The wastewaters contain the spent sodium compounds. It is well known that certain soils tend to absorb and retain the sodium ions. Ultimately these soils undergo a physical damage as manifested in very low permeability, high runoff and sparse vegetation. Obviously, the initiation of a salt-affected soil is not desirable on a land disposal area used by a cannery.

The research program reported herewith was designed to monitor the sodium status of soils used for the disposal of sodium wastewater. The study has been underway for two years. The salinity status of the soils are characterized in terms of calcium carbonate equivalent, electrical conductivity of the soil extract and degree of saturation of the exchange complex by sodium.

Cation Exchange in Soils

Around 1850, Way at Rothamsted discovered the principle of ion exchange in soils. He established that the soluble nutrients from fertilizers were held by the fine material in a soil and that an equal amount of material was displaced during this exchange. This fundamental principle was established three decades before chemistry developed the law of mass action.

When it was demonstrated that clays and organic matter carried a net negative charge, research on the cation exchange properties of soils developed rapidly. It was established that cations were held to the soil particle surfaces by varying adsorption affinities as in the series:

$$H > Al > Ca = Mg > K = NH_4 > Na$$

The adsorption affinity decreases as the hydrated radius of the ion increases. Apparently the relatively large hydrodynamic radius of the sodium ion lessens the tenacity with which the ion is held on exchange sites. This relationship becomes very important in avoiding the commencement of a salt-affected soil.

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The quantity of ions retained by a soil in an exchangeable status essentially defines the cation exchange capacity (CEC) of a soil. The quantity of ions on the exchange complex increases with increasing amounts of clay and organic matter. The CEC of a soil is expressed as the milliquivalents (me) of exchangeable ions retained by 100 grams of soil. One milliequivalent weight of hydrogen is 0.001 of sodium 0.023 and calcium 0.02 grams per 100 grams of soil. If it were determined that a soil had 4 me of exchangeable sodium per 100 g of soil (4 mg/100g). This would be equivalent to 920 parts per million of sodium or about 1840 pounds of sodium per 6-inch depth of soil.

Terminology

The following definitions of soil terms are recommended for application to soil samples and for application to field soil for management purposes (1):

Sodic soil - Soil that contains sufficient exchangeable sodium to interfere with the growth of most crop plants. For purposes of definition, soil for which the exchangeable-sodium-percentage is 15 or more.

Saline soil -Soil that contains sufficient soluble salt to interfere with the growth of most crop plants. For purposes of definition, soil for which the conductivity of the saturation extract is 4 or more millimhos per cm at 25°C.

Salt-affected-soil - Soil that has been adversely modified for the growth of most crop plants by the presence or action of soluble salts. The term includes soil having an excess of soluble salts, or an excess of exchangeable sodium or both.

DISPOSAL SITE

The disposal site lies within a large meander of the Sydenham River, near Dresden, Ontario. The soils have developed from lacustrine and alluvial materials deposited by the present river and its ancient predecessors. The area is imperfectly to poorly drained: the texture of the surface soils range from a sandy loam to silt loam (Table 1). Soil B, an imperfectly drained sandy laom was underlain by a calcareous clay at approximately 23 inches (Table 1). The natural slopes are dominantly less than three percent.

The area has been used for approximately 12 years as a disposal site for cannery wastewaters. An underground tile drainage system was installed soon after the area was acquired by the cannery.

METHODOLOGY

Soil samples were obtained on five occasions, from July 1971 to November 1972, Table 4. Samples were obtained by digging pits to expose the various soil horizons for sampling.

The cation exchange capacity was determined by treating a sample of soil with sodium acetate, pH 8.2 to replace ions on the exchange sites. The concentration of sodium ions was determined by atomic absorption spectroscopy. The pH was determined on a 1:1 soil water suspension. Organic matter was estimated by the wet combustion technique using potassium dichromate, sulphuric acid and back titrating with ferrous sulphate. To determine the calcium carbonate equivalent, a sample of soil was treated with 6 N hydrochloric acid and the loss in weight expressed as calcium carbonate.

Table 1. Physical and chemical properties of two soils used for the disposal of wastewater from a cannery.

Soil A: Poorly drained

Depth (in)	pH[1]	O.M.[1] %	C.E.C.[1] me/100g	Sand[2]	Silt[2]	Clay[2]	1/3-bar[3]
0-10	6.6	4.4	18.5	65	22	13	22
10-30	6.9	0.7	10.0	70	21	9	16
30-33	6.9	0.6	8.2	82	13	5	10
33+	7.4	0.7	7.4	73	21	6	10

Soil B: Imperfect drainage

0-18	7.6	1.2	5.9	70	27	3	10
18-23	7.5	0.5	8.5	76	13	11	11
23+	7.6	0.7	21.7	3	55	42	33

1. Averaged values from five times of sampling.
2. Sand (2.0 to 0.05 mm); silt (0.05 to 0.002 mm); clay (< 0.002 mm).
3. The laboratory approximation of maximum water-holding capacity under field conditions of good natural drainage.

DISCUSSION OF RESULTS

Salt-affected soils may be characterized by several chemical determinations, primarily the concentration of soluble salts in the soil solution and a measurement of the amount of sodium on the soil exchange complex.

As the quantity of sodium accumulates in the soil solution, exchangeable sodium tends to increase if the sodium can compete favourably with soluble calcium or magnesium for exchange sites. For effective competition, the concentration of sodium must exceed the concentration of calcium plus magnesium.

Calcium carbonate alone is generally an ineffective source of calcium in soils with a high pH (< 8.5) because of the low solubility of the carbonate. In some arid salt-affected soils with an excess of lime, the replacement of sodium by calcium is effected by the addition of elemental sulphur. Soil organisms oxidize the sulphur to form sulphuric acid which reacts with the lime to form gypsum, calcium sulphate. The addition of calcium sulphate is equally effective in inducing the exchange of sodium for calcium.

In soils having free calcium carbonate, hydrolysis occurs with free calcium ions being brought into solution. For this reaction to occur soil water is required. Presumably, less free calcium is released if the calcium carbonate equivalent of the soil is low or if the pH is particularly high due to sodium compounds in the soil solution. The hydrolysis of the calcium carbonate and the replacement of sodium on the exchange complex by the free calcium is shown in the following equation:

$$2Na_{ad} + CaCO_3 + H_2O \rightleftharpoons Ca_{ad} + 2Na^+ + HCO_3^- + OH^-$$

In an interpretation of the above reaction, Bower and Goertzen (2) pointed out that the reaction proceeds to the right as the water content of the soil is increased. If the soil is leached and if sufficient $CaCO_3$ is present the reaction continues to the right owing to the removal of the HCO_3^- and OH^- and Na^+ until all of the adsorbed sodium (Na_{ad}) is replaced.

The calcium carbonate equivalents of the soils from the cannery disposal site are given in Table 2. The equivalent is expressed as a percentage of the oven-dry weight of soil. If an acre-furrow slice of soil is assumed to weigh 2 million pounds, then 1.0 percent equivalent would be equivalent to 20,000 pounds of calcium carbonate. In both soils the calcium carbonate equivalent tends to increase with depth suggesting that the normal soil leaching process removes the carbonate in solution. Comparing the two soils, the generally lower equivalent values in the imperfectly drained site may be related to a better internal soil drainage which would be enhanced by the coarse-textured nature of the materials over the clay subsoil. The existence of a calcium carbonate equivelent in all layers of both soils, suggests that the replacement of sodium for calcium as described previously is entirely possible in these soils.

The conductivity measurement reflects the concentration of soluble salts in the soil solution. The predominant ions contributing to the conductivity include sodium and potassium. In general, the solubilities of calcium and magnesium compounds are too low to have an effect on the measurement. Four classes of salinity hazards have been proposed and related to the electrical conductivity (Table 3).

The conductivity values listed in Table 2 are averaged values for five times of sampling. On one occasion, July '71 the conductivity exceeded 750 micromhos and that was in the 30 to 33-inch layer of the poorly drained soil.

As the electrical conductivity of all samples for all dates was less than the 750 value, with one exception, it would appear that at this time salinity is not a problem.

In diagnosing the salinity hazard for field soils considerable emphasis is placed on the percentage saturation of the cation exchange complex by sodium (Table 4). The extent of saturation by potassium is included in Table 4 because of the tendency for the ion to act as a dispersing agent in relatively high concnetrations. However, it is expected that potassium would be removed from the soil by a cover crop in greater amounts than the sodium ion.

Table 2. The calcium carbonate equivelent and the conductivity of two soils used for the disposal of wastewater from a cannery

Soil A: Poorly drained

Depth (in)	Calcium carbonate equivalent %/wt[1]	Conductivity micromohos[2]
0-10	0.6	250
10-30	0.4	200
30-33	1.7	350
33+	9.2	300

Soil B: Imperfect drainage

Depth (in)	Calcium carbonate equivalent %/wt[1]	Conductivity micromohos[2]
0-18	0.5	150
18-23	0.8	200
23+	5.8	300

1. Averaged values from five times of sampling.

2. Represents the conductivity of 1.0 cm^3 of soil solution placed between two platinized electrodes each having an area of 1.0 cm^2 and place 1.0 cm apart. The values are the average of five determinations corresponding to five times of sampling.

Table 3. Salinity hazards in relation to electrical conductivity.

Salinity hazard	Conductivity, micromohs
low	< 750
medium	750 to 1500
high	1500 to 3000
very high	> 3000

Table 4. Percentage saturation of the cation exchange complex by sodium and potassium for five times of sampling.

Depth (in)	July 71		Nov 71		Apr 72		Aug 72		Nov 72	
	Na	K	Na	K	Na	K	Na	K	Na	K
				Soil A: Poorly drained						
0-10	2.3	3.2	6.6	3.7	1.8	4.2	4.9	3.8	7.3	2.9
10-30	2.5	1.3	5.8	1.6	3.7	2.8	3.3	2.4	6.1	2.1
30-33	4.6	1.7	5.2	2.0	3.4	2.1	3.6	2.2	4.8	1.9
33+	4.3	2.0	4.6	1.4	3.9	1.5	2.8	1.7	4.0	1.5
				Soil B: Imperfect drainage						
0-18	2.7	7.6	6.1	5.5	3.2	2.9	11.7	8.3	8.4	5.5
18-23	4.4	2.7	7.5	1.8	2.9	1.0	5.4	2.3	7.8	4.7
23+	5.2	1.1	5.0	1.5	3.6	1.0	4.8	1.6	6.0	1.9

It has been proposed, that a salinity problem should be manifested in soils when 15 percent or more of the exchange complex was occupied by sodium (1). As indicated in Table 4, there was one occasion when the sodium or the sodium plus potassium occupied 15 percent of the exchange complex. In most instances, greatest degree of saturation by sodium and potassium occurred in November '71 and '72. Normally the discharge of alkali waste would end in early Augsut followed by wastewater from processing tomatoes without any sodium compounds. Presumably, the winter and spring precipitation encouraged leaching and the removal of the ions from the soil solution in the upper soil layers. The data for April '72 suggest that there was a downward movement of the sodium ions. More data are required to characterize the downward movement.

CONCLUSIONS

Where soils are used for the disposal of wastewaters containing alkali, particularly sodium, there is a hazard that sodium would accumulate on the exchange complex and eventually induce a salt-affected soil.

Over a two-year period the sodium relationships in two soils used for the disposal of alkali wastes from a cannery have been monitored. Three criteria were used to characterize the soil salinity condition: (1) calcium carbonate equivalent, (2) electrical conductivity, and (3) percentage saturation of the exchange complex by sodium. None of the criteria indicated that salinity was a problem. The periodic testing is to be continued.

If future analysis indicate a salinity hazard is developing, as manifested by a gradual and persistent increase in the degree of saturation by sodium, elevated levels of conductivity or the virtual absence of calcium carbonate, remedial measures would include the application of calcium sulphate.

ACKNOWLEDGEMENTS

This research was carried out under a contract agreement with Canadian Canners Ltd., Burlington, Ontario, Canada.

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TREATMENT OF FISH & VEGETABLE PROCESSING WASTE-LAGOON EFFLUENT BY SOIL BIO-FILTRATION

by

V. K. Chawla*

ABSTRACT

In October 1971, an experiment on spray irrigation of fish and vegetable processing lagoon-effluent was conducted on land in Wheatley, Ontario, to investigate the optimum spray application rate and the nutrient removal efficiency of the Soil Bio-filtration System. Three application rates of: 11.5 cm (4.5"), 7.6 cm (3.0") and 5.1 cm (2.0") per week per acre were studied for a period of six weeks from October 25 to December 5, 1971. The characteristics of lagoon-effluent sprayed and the land percolate collected from the experiment were regularly monitored for Biochemical Oxygen Demand (BOD); Chemical Oxygen Demand (COD); Soluble Phosphorus (S P); Total Phosphorus (T.P.); Organic Nitrogen (Org.-N); Nitrate Nitrogen (NO_3-N); Ammonia Nitrogen (NH_3-N); Total Nitrogen (T.N.); Total Carbon (T .C.) and Organic Carbon (Org.-C).

The application rate of 7.6 cm (3") per week per acre proved to be the optimum loading rate and yielded a mean land percolate of only 14 mg/1 BOD, 41 mg/1 COD and 5 mg/1 NO_3-N. The rate of 5.1 cm (2") proved to be limiting due to high concentrations of NO3-N (10.2 mg/1) in the soil percolate and the rate of 11.5 cm (4.5") was limiting due to high concentrations of BOD and COD (36 & 97 mg/1) in the resulting percolate from the soil bio-filter.

Except for nitrate nitrogen, the nutrient removal efficiencies were highest from 5.1 cm (2") spray application rate (100% BOD, 99% COD, 97% Soluble P, 94% Total P, 86% NH_3-N, 89% Org.-N, 70% Total N, 85% Org.-C and 65% Total C) and lowest from 11.5 cm (4.5") application rate (91% BOD, 85% COD, 84% Soluble P, 85% Total P, 72% NH_3-N, 67% Org.-N, 64% Total N, 44% Org.-C and 45% Total C).

Statistically at 99% confidence level, the differences in the quality of soil percolate were significant between three application rates for BOD, COD, Total P, Total N, NO_3-N, Total C, Org.-C, pH and conductance.

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INTRODUCTION

During the last decade, fish processing industries have been practicing various methods to treat their wastes, but the effluent quality has not always been very satisfactory to meet the increasingly high standards of water quality for preserving our fresh water lakes and rivers.

Omstead Fisheries, is the largest fresh water fish processing plant in Canada. It is located at Wheatley, Ontario, a town on Lake Erie near Windsor. The plant processes about 25-30 million pounds of perch and smelt every year and requires huge quantities of water for their processing. The fish and vegetable processing waste of the plant at the time of this investigation was mixed, neutralized and approximately one-half of the flow was passed to the lagoon which had a volume of about 560,000 Imperial gallons where it was partially aerated by a surface aerator. This arrangement was a pilot scale installation and all waste will soon receive full lagoon treatment with the completion of a second cell.

The aerated effluent from the lagoon passed over a weir and discharged into Lake Erie with average concentrations of BOD-387 mg/l, COD-643 mg/l, Soluble P-3.7 mg/l, Total P-14.2 mg/l, Organic N-31.5 mg/l, Total N-46.1 mg/l, Total C-124 mg/l and Organic C-82 mg/l.

To further improve the quality of the effluent, additional treatment was considered necessary. A feasibility study of spray irrigation of partially aerated lagoon effluent on land was, therefore, undertaken to evaluate the performance and nutrient removal efficiency of the soil bio-filtration at 5.1 cm (2"), 7.6 cm (3") and 11.5 cm (4.5") per week per acre application rate.

LITERATURE REVIEW

Land disposal is one of the oldest methods of treating wastewater employed by man. Historical literature shows that municipal wastes were applied to neighbouring farmland at the City of Berlin in the sixteenth century as reported by Williams, et al (1). Due to new developments resulting from scientific knowledge and present technology in land treatment techniques, this method is considered as an advanced method of wastewater treatment.

Spray application of waste effluent on vegetation covered soil systems has been considered one of the most effective treatment modes of land treatment technology. This system has received a lot of attention during the last few decades as reported by Law (2). Soil filtration has been employed as an efficient and economical way of treating and disposing industrial and municipal wastes as reported by Luley (3) for vegetables and canneries waste, by Bloodgood (4) and Vercher, et al (5) for pulp and paper mills and by Larson (6), Foster, et al (7), Kardos (8) and Wilson (9) for sewage effluents.

The reclamation of wastewater by the soil system usually occurs in the first few feet of soil mantle as reported by Amarmy (10), Baars (11), Bendixen, et al (12), McGauhey et al (13), McMichael, et al (14), and Parizek, et al (15). Physical adsorption, chemical precipitation, oxidation-reduction, organic chelation, ion exchange and biological assimilation are the soil processes involved which work accumulatively for the high degree renovation of wastewaters.

Phosphates are immobilized in the upper layer of the soil and appear in low concentrations in the renovated water as reported by Parizek, et al (15) and Taylor (16).

Merrell et al (17) accomplished BOD and COD reductions of 99 and 75 percent respectively by use of soil filters for reclaiming treated wastewaters from the City of Santee, California. Bocko (18) listed total bacteria reductions of 85-99 percent under field conditions and 99-99.9 percent in lysimeters.

Laverty et al (19) used a soil filtration system as a tertiary treatment method for improving the quality of Hyperion treatment plant effluent so that it could be injected into the ground-water aquifers underlying the Los Angeles basin. Parizek et al (15) achieved excellent reductions for all elements measured in their experiment by maintaining an aerobic soil environment. Treated municipal waste effluent from the State College (Pennsylvania) Treatment Plant was applied onto crop and forest lands by sprinkler irrigation at the rate of 5.1 cm (2") per week per acre. After 18 months, during which time 289.6 cm (114") of effluent were applied to the land, the percolate samples extracted from the soil at a depth of 15 cm (6") in a red pine forest contained only 0.15 mg/l P, 12.1 mg/l NO_3-N, 1.3 mg/l Org.-N, 10.8 mg/l K, and 77.3 mg/l Cl as compared to 7.8 mg/l P, 13.6 mg/l NO_3-N, 3.6 mg/l Org.-N, 15.7 mg/l K and 39.6 mg/l Cl in the applied effluent.

Temple University, Pennsylvania (20) in their report on the beneficial use of wastewater through land treatment has described some industrial infiltration facilities with highly successful results. Seabrook Farms (New Jersey) installation built in 1949-50 is spraying about 12 million gallons of vegetable processing waste on 200 acres of wooded land per day. On the basis of an actual 84 acres of wetted land, the application rate is about 4.8 inches per day. Tests over a three season period on samples drawn from monitoring wells show an average BOD content from 0.8 to 3.8 mg/l. This is estimated to be a 99.3% to 99.7% BOD reduction from the content of the sprayed wastewater.

The Campbell Soup Company (Paris, Texas) has been in operation since 1964 and produces wastewater in quantities up to 3.6 MGD. The design application rate was 0.25 inches per day in winter and 0.50 inches in summer for an operational schedule of six hours wetting and 18 hours dry from late fall to early spring and eight hours wetting and 16 hours dry during the four or five summer months. The removal efficiencies on a mass basis have been given at 99% BOD, 90% Total P, 91% Total N, 98% Total Suspended Solids and 91% Total Organic Carbon.

Though land treatment technology has been applied as an advanced wastewater treatment method for different industrial and municipal effluent, there is no published information in the literature on the treatment of combined fish and vegetable processing waste by using a soil bio-filtration system. It was, therefore, considered desirable to investigate a tertiary treatment system for an aerated fish and vegetable processing lagoon effluent by spray irrigation on land.

EXPERIMENTAL PLAN AND METHODS

Aerated lagoon effluent was applied to three experimental plots of a specially constructed tile drained field with a medium textured sandy loam top soil and a level topography. Weekly spraying loads at 5.1, 7.6 and 11.5 cm (2, 3 & 4.5 inches) per acre were applied onto three different plots respectively. Spraying schedules were on an 8-hour wet and 16-hour dry basis for three consecutive days of each week (Monday, Tuesday & Wednesday) and on the remaining four days of the week (Thursday, Friday, Saturday & Sunday) the soil system was given a rest (no spraying) to regenerate its physio-bio-chemical capacity for treatment.

The field lay-out (Figure 1) shows each experimental plot covered an actual sprayed area of about 0.072 hectares (0.18 acres). Experimental plots were separated from each other by 15.2 meters (50') wide control plots and bordered on each side by a 10.1 cm (4") clay tile placed at a depth of 0.61 meters (2') underground. Another central tile ran through each experimental plot parallel to the border tiles at an equal distance of 15.2 m (50') apart.

Four circular sprinklers, each capable of spraying 15.2 m (50') in diameter, were used on each experimental plot, to create the actual sprayed area of about 0.072 hectares (0.18 acres). Nozzle diameters of 1.1, 1.4 and 1.7 cm (7/16, 9/16 and 11/16 inches) were capable of delivering the required spray loading onto each plot with the pump and piping available. Sprinkler heads were elevated 30.5 cm (12") above ground level.

Aerated lagoon effluent was pumped from the lagoon wet well with a centrifugal pump, powered by an 8.25 H.P. gasoline engine, to a 3.8 cm (1.5") PVC header pipe which extended about 152 meters (500 feet) to the furthest experimental plot. Flow from the header to each lateral connector was regulated with a 3.8 cm (1.5") globe valve and metered with cumulative flow water meters. Flow from the meters passed into dual 3.8 cm (1.5") polypropylene pipe (50 PSI) to the sprinkler heads.

Drainage tiles were intersected and exposed by a trench in which 20 gallon plastic drums collected leachate from each tile. Leachate overflowed the collection drums into the trench and flowed into Lake Erie.

Lagoon effluent as well as tile percolate were collected daily (Monday to Friday) and analyzed for BOD, COD, Soluble P, Total P,

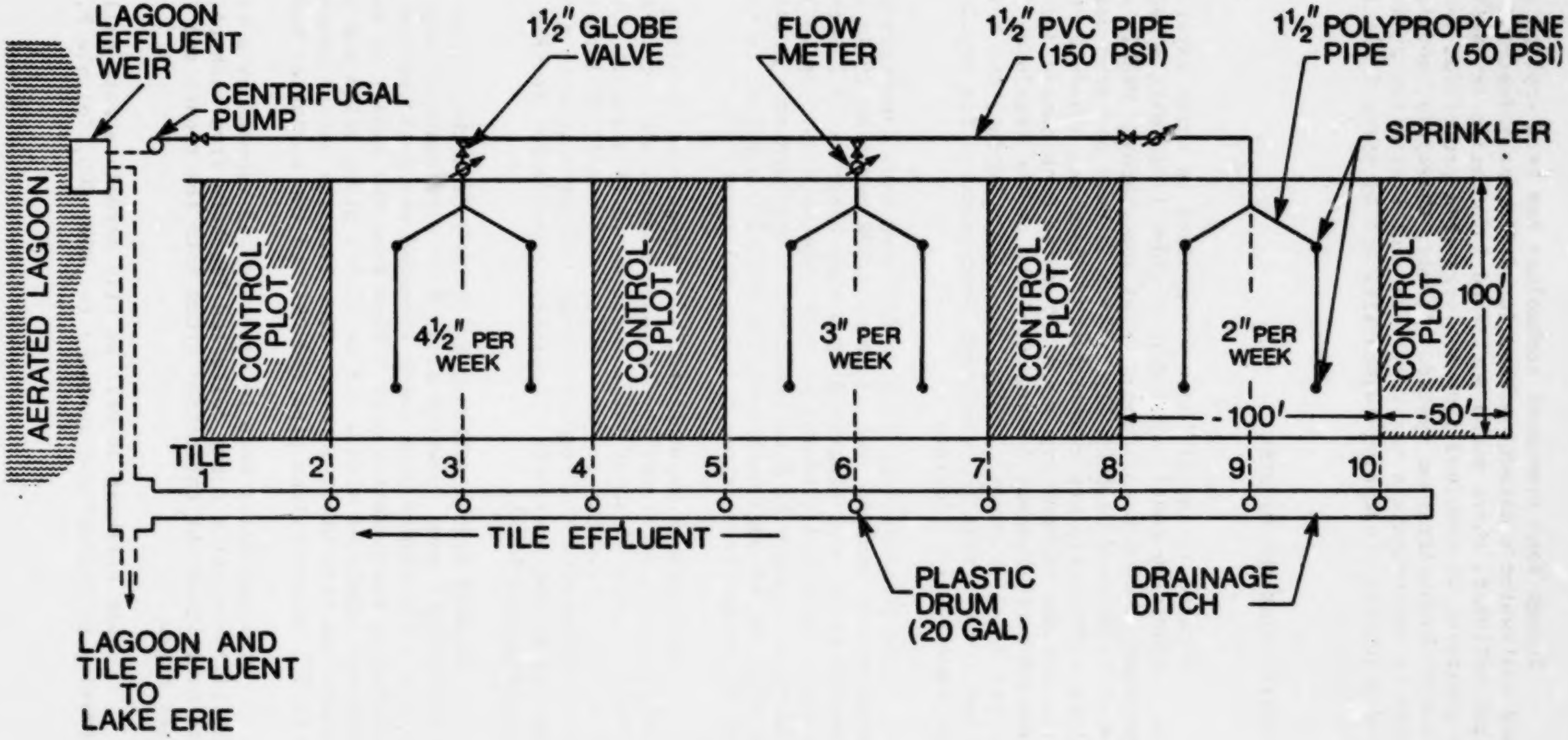
LAGOON EFFLUENT WEIR
CENTRIFUGAL PUMP
1½" GLOBE VALVE
FLOW METER
1½" PVC PIPE (150 PSI)
1½" POLYPROPYLENE PIPE (50 PSI)
SPRINKLER
AERATED LAGOON
CONTROL PLOT
4½" PER WEEK
CONTROL PLOT
3" PER WEEK
CONTROL PLOT
2" PER WEEK
CONTROL PLOT
100'
100'
50'
TILE 1
2
3
4
5
6
7
8
9
10
TILE EFFLUENT
PLASTIC DRUM (20 GAL)
DRAINAGE DITCH
LAGOON AND TILE EFFLUENT TO LAKE ERIE

FIG. 1 WHEATLEY SPRAY IRRIGATION — FIELD LAYOUT 1" = 50'

NH_3-N, NO_3-N, Org.-N, Total N, Org.-C, Total C, pH and conductance using standard methods (21) of analysis. The BOD, COD, pH and conductance analysis were performed on site and the soluble and total nutrients were analyzed at the Wastewater Technology Centre at Burlington, Ontario.

RESULTS & DISCUSSION

The concentrations of lagoon effluent were monitored daily prior to spray application on land. The values averaged out on a weekly as well as on overall experiment basis are given in Table 1.

From the perusal of data in Table 1, it is apparent that the concentrations of lagoon effluent varied considerably over a period of six weeks except for pH and conductance. The overall mean concentrations of BOD, COD, Total P, Total N, and Organic Carbon entering Lake Erie were high by normal standards of water quality and the need for additional treatment of some form was clearly indicated.

Spray Irrigation on Land

The lagoon effluent was sprayed on land at three different rates of application - 5.1 cm (2"), 7.6 cm (3") and 11.5 cm (4.5") per acre per week for a total period of six weeks from October 25 to December 5 and the concentrations of percolate from the soil system were monitored daily (5 days a week) to determine changes in lagoon effluent after infiltration and to study the removal efficiency of the soil bio-filtration for different nutrients.

The weekly mean concentrations of soil percolate collected from three rates of spray application - 5.1 cm (2"), 7.6 cm (3") and 11.5 cm (4.5") per week per acre are given in Tables 2, 3 and 4 respectively.

The examination of values for all the measured parameters given in Table 2, 3 and 4 do not show considerable difference from one week to another, but are statistically significant from one rate of application to another. This indicates further that the soil system is capable of sustaining weekly shock loads of lagoon effluent. It is evident from the above data that the application rate of 5.1 cm (2") was highly effective in reducing the concentrations of BOD, COD, Total and Soluble P, Organic N and Organic Carbon, while the application rate of 11.5 cm (4.5") was least effective in reducing these nutrient concentrations to a satisfactory acceptable level.

The NO_3-N on the other hand had the highest concentrations of 10.2 mg/l from the lowest application rate. This is most probably due to a faster transformation of organic nitrogen to the nitrate form because of biochemical oxidation at the 5.1 cm (2") rate as compared to the 11.5 cm (4.5") rate of application. This high concentration of NO_3-N (10.2 mg/l) was considered a limiting factor on the performance of the 5.1 cm (2") application rate by normal standards of water quality. Though the NO_3-N concentration from 11.5 cm (4.5") application

TABLE 1 WEEKLY MEAN CONCENTRATIONS OF LAGOON EFFLUENT

WEEKS	BOD_5	COD	ORTHO-P	TOTAL-P	NH_3-N	NO_3-N	ORG.-N	TOTAL-N	ORG.-C	TOTAL-C
1	612	935	5.1	28.0	18.2	0.7	13.5	32.4	95	116
2	239	1,105	5.6	10.2	20.3	3.9	47.1	71.3	89	132
3	196	562	3.8	16.3	18.2	0.5	9.7	28.4	89	131
4	393	463	2.7	16.0	12.0	11.0	21.5	44.5	93	161
5	403	387	1.9	8.4	0.8	0.6	51.3	52.7	70	107
6	478	403	3.2	6.1	0.7	0.5	46.1	47.3	54	96
$\bar{x}$	387	643	3.7	14.2	11.7	2.9	31.5	46.1	82	124

$\bar{X}$ - IS THE POPULATION MEAN

- CONCENTRATIONS - MG/L EXCEPT PH AND CONDUCTIVITY (μMHOS)

TABLE 2

WEEKLY MEAN CONCENTRATIONS OF PERCOLATE FROM 5.1 CM (2") PER WEEK PER ACRE APPLICATION RATE

WEEKS	BOD_5	COD	ORTHO-P	TOTAL-P	NH_3-N	NO_3-N	ORG.-N	TOTAL N	ORG.-C	TOTAL-C
1	1	8	0	1.5	2.9	10.1	6.3	19.3	7	31
2	0	6	0	1.4	3.5	8.7	0.5	12.7	4	40
3	0	6	0	0.7	0.2	9.8	1.6	11.6	2	43
4	0	10	0	0.3	0.1	10.1	1.6	11.8	14	49
5	1	5	0.3	0.3	0.1	11.4	2.7	14.2	19	52
6	1	6	0.1	0.1	0.1	10.0	2.0	12.1	26	57
$\bar{X}$	1	7	0.1	0.8	1.6	10.2	3.4	13.9	12	44

$\bar{X}$ - IS THE POPULATION MEAN

- CONCENTRATIONS - MG/L EXCEPT PH AND CONDUCTIVITY (μMHOS)

TABLE 3 WEEKLY MEAN CONCENTRATIONS OF PERCOLATE FROM 7.6 CM (3") PER WEEK PER ACRE APPLICATION RATE

WEEKS	BOD_5	COD	ORTHO-P	TOTAL-P	NH_3-N	NO_3-N	ORG.-N	TOTAL-N	ORG.-C	TOTAL-C
1	7	28	0.1	1.5	3.6	5.3	4.4	13.3	22	51
2	11	40	0.3	1.8	3.9	7.2	1.0	12.1	20	58
3	10	41	0.3	1.7	3.3	4.8	2.9	11.0	23	51
4	10	35	0.6	1.3	1.7	5.5	2.6	9.8	32	67
5	20	64	0.6	1.0	0.2	2.6	4.7	7.5	34	52
6	25	47	0.2	0.4	0.1	3.5	5.9	9.5	39	64
$\bar{X}$	14	41	0.3	1.3	2.3	5.0	4.3	10.7	29	60

$\bar{X}$ - IS THE POPULATION MEAN

- CONCENTRATIONS - MG/L EXCEPT PH AND CONDUCTIVITY (µMHOS)

Table 4 Weekly Mean Concentrations of Percolate From 11.5 cm (4.5") Per Week Per Acre Application Rate

Weeks	BOD_5	COD	Ortho-P	Total-P	NH_3-N	NO_3-N	Org.-N	Total-N	Org.-C	Total-C
1	33	95	0.8	3.8	6.9	3.8	8.4	19.1	51	74
2	32	100	0.7	2.4	6.6	4.6	4.8	16.0	44	68
3	17	90	0.6	3.7	3.3	5.3	8.7	17.3	35	56
4	22	99	0.6	1.8	1.5	6.0	9.5	17.0	60	80
5	73	131	0.5	1.0	0.3	3.3	16.0	19.6	47	69
6	52	78	0.4	0.6	0.2	2.4	10.9	13.5	42	64
X	36	97	0.6	2.2	3.3	4.2	10.3	16.8	46	68

$\bar{X}$ - IS THE POPULATION MEAN

- CONCENTRATIONS - MG/L EXCEPT PH AND CONDUCTIVITY (μMHOS)

rate was low (4.2 mg/1), the concentrations of BOD (36 mg/1) were undesirable according to accepted industrial waste control criteria in Ontario as given by OWRC (22) which rendered this rate of application unacceptable and limiting.

The soil percolate concentrations from the 7.6 cm (3") application rate were judged satisfactory due to low BOD (14 mg/1), Soluble P (0.3 mg/1), Total P (1.3 mg/1), NO_3-N (5.0 mg/1) and Org.-N (5.0 mg/1).

The variations of nutrient concentrations in tile percolates from different application rates based on overall experimental means have been plotted in Figure 2. It is quite apparent from this figure that the increasing concentrations of BOD, COD, Org.-C, Total C, Organic N, Total P, NH_3-N and Soluble P in the tile percolates were approximately linear with increasing rates of application. The concentrations of NO_3-N, however, decreased with the increasing rates of application and gave a negative relationship with rates. It is also clear from Figure 2 that an application rate of 7.6 cm (3") per acre per week yielded BOD value $\leq$ 15 mg/1, NO_3-N $\leq$ 5 mg/1, Org.-N $\leq$ 5 mg/1 and Total P $\leq$ 1.3 mg/1 which are acceptable water quality effluent standards.

Analysis of Variance

A two-way analysis of variance was performed on the daily mean concentrations of percolate collected from three different application rates (2, 3 and 4.5 inches) and the summary of data is given in Table 5. The results of Table 5 clearly show that the differences of concentrations in percolates produced from three application rates were statistically significant at 99% confidence level.

The perusal of data further shows that all three rates of application produced different quality of renovated water and their acceptance or rejection has been judged based on the water quality criteria for Ontario.

Nutrient Removal Efficiencies

Weekly and overall experimental mean percentage removal of BOD, COD, Ortho P, Total P, NH_3-N, Total N, Organic C and Total Carbon from lagoon effluent under 5.1 cm (2"), 7.6 cm (3") and 11.5 cm (4.5") rates of application are given in Tables 6, 7 and 8.

The examination of the above Tables clearly indicates that the highest removal efficiencies were observed under lowest rate of application 5.1 cm (2") whereas the highest application rate of 11.5 cm (4.5") yielded lower removals. Under all three rates of application (4.5, 3 and 2 inches) the overall removal efficiencies ranged from 91 to 100% for BOD, 85 to 99% for COD, 84 to 97% for Ortho P, 85 to 94% for Total P, 72 to 86% for NH_3-N, 67 to 89% for Org.-N, 64 to 70% for Total N, 44 to 85% for Org.-C, and 45 to 65% for Total Carbon.

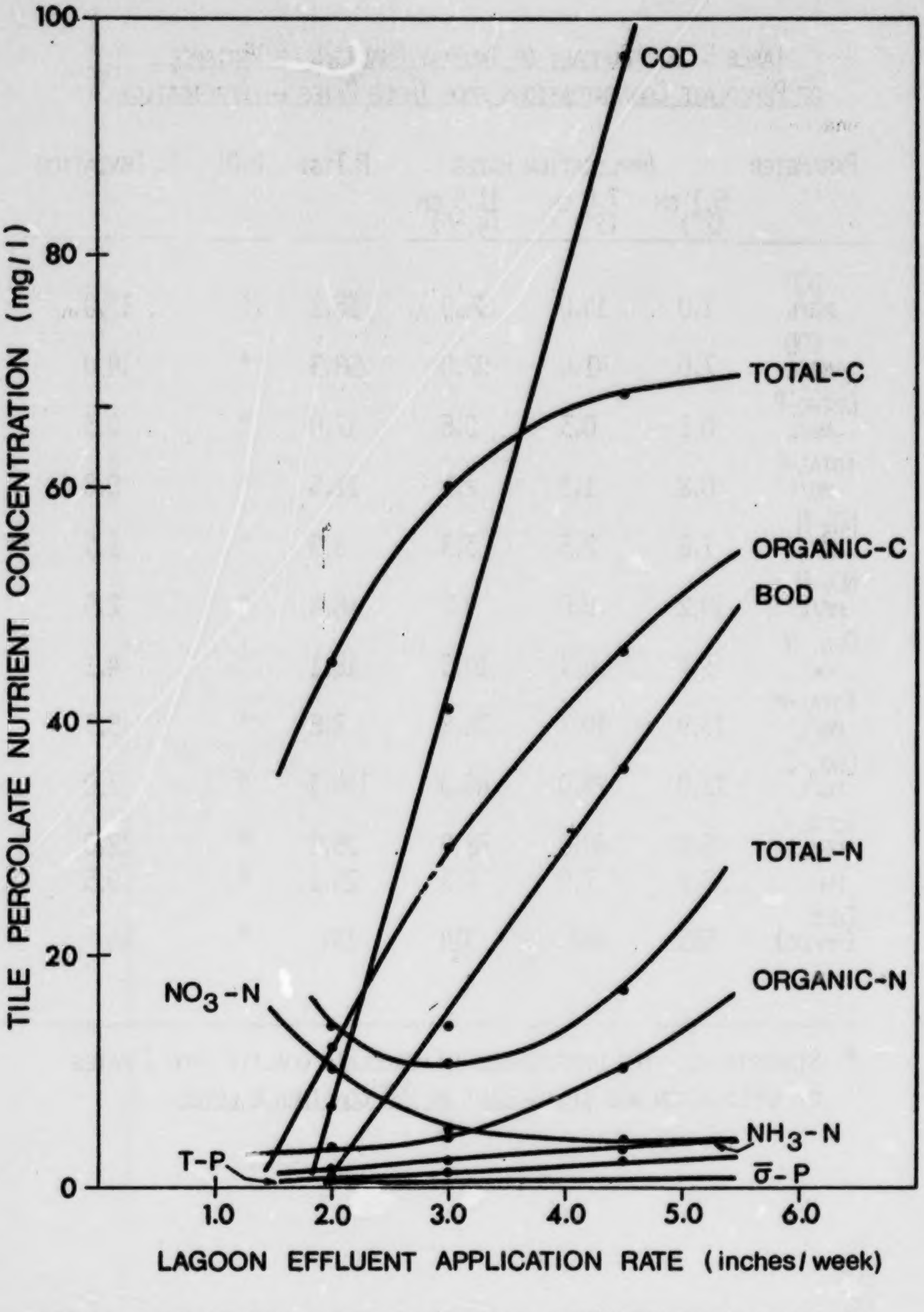

FIG. 2 VARIATIONS OF NUTRIENT CONCENTRATIONS IN TILE PERCOLATES WITH APPLICATION RATE

TABLE 5 - SUMMARY OF TWO-WAY ANALYSIS OF VARIANCE OF PERCOLATE CONCENTRATIONS FROM THREE RATES OF APPLICATION

PARAMETER	APPLICATION RATES			F TEST	P.01	S. DEVIATION
	5.1 CM (2")	7.6 CM (3")	11.5 CM (4.5")			
BOD MG/L	1.0	14.0	36.0	56.2	*	13.0
COD MG/L	7.0	41.0	97.0	298.5	*	14.0
ORTHO-P MG/L	0.1	0.3	0.6	17.0	*	0.3
TOTAL-P MG/L	0.8	1.3	2.2	21.5	*	0.8
NH_3-N MG/L	1.6	2.3	3.3	8.9	*	1.5
NO_3-N MG/L	10.2	5.0	4.2	46.4	*	2.5
ORG.-N MG/L	3.4	4.3	10.3	16.1	*	4.1
TOTAL-N MG/L	13.9	10.7	16.8	8.6	*	5.3
ORG.-C MG/L	12.0	29.0	46.0	144.3	*	7.0
TOTAL-C MG/L	45.0	60.0	68.0	26.6	*	12.0
PH	7.9	7.4	6.8	25.1	*	0.5
COND. (μMHOS)	535	447	314	134	*	44

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* STATISTICALLY THE DIFFERENCES IN PERCOLATE QUALITY FROM 3 RATES OF APPLICATION ARE SIGNIFICANT AT 99% CONFIDENCE LEVEL.

Table 6

Weekly Mean Percentage removals

From 5.1 cm (2") per week per acre application rate

Weeks	BOD_5	COD	Ortho-P	Total-P	NH_3-N	Org.-N	Total-N	Org.-C	Total-C
1	100	99	100	95	84	53	40	93	73
2	100	99	100	86	83	99	82	97	70
3	100	99	100	96	99	83	59	98	67
4	100	98	100	98	99	91	73	85	70
5	100	99	96	96	88	95	73	73	51
6	100	99	97	98	86	96	74	52	41
$\bar{X}$	100	99	97	94	86	89	70	85	65

$\bar{X}$ - is the population mean

TABLE 7

WEEKLY MEAN PERCENTAGE REMOVALS
FROM 7.6 CM (3") PER WEEK PER ACRE APPLICATION RATE

WEEKS	BOD_5	COD	ORTHO-P	TOTAL-P	NH_3-N	ORG.-N	TOTAL-N	ORG.-C	TOTAL-C
1	99	97	98	95	80	67	59	77	56
2	95	96	95	82	81	98	83	77	56
3	95	93	92	90	82	70	61	74	61
4	97	92	78	92	86	88	78	66	58
5	95	83	68	88	75	91	86	51	51
6	95	88	94	93	86	87	80	28	33
$\bar{X}$	96	94	92	91	80	86	77	65	52

$\bar{X}$ - IS THE POPULATION MEAN

TABLE 8

WEEKLY MEAN PERCENTAGE REMOVALS FROM 11.5 CM (4.5") PER WEEK PER ACRE APPLICATION RATE

WEEKS	BOD_5	COD	ORTHO-P	TOTAL-P	NH_3-N	ORG.-N	TOTAL-N	ORG.-C	TOTAL-C
1	95	90	84	86	62	38	41	46	36
2	87	91	88	76	67	90	78	51	43
3	91	84	84	77	82	-	39	61	57
4	94	79	75	89	88	63	62	35	50
5	82	66	74	88	63	68	63	33	36
6	89	81	88	90	71	76	71	22	33
$\bar{X}$	91	85	84	85	72	67	64	44	45

$\bar{X}$ - IS THE POPULATION MEAN

The drop in the removal efficiency of organic carbon under all three rates of spraying during the 5th and 6th weeks of operation (Nov. 22 - Dec. 5) was apparently due to reduction of biological activity in the soil at lower temperatures and possibly resulted in lack of carbon assimilation by the soil microorganism.

The overall experimental nutrient removal efficiencies are also shown in Figure 3. All the decreasing removal efficiencies have approximately a linear relationship with increasing spray application rates except for total nitrogen which is dependent on NO_3-N transformation from organic nitrogen. The highest rate of application, evidently created a greater anaerobic environment which was not conducive to aerobes to break down organics for assimilation and was unsuitable for effective chemical oxidation, physical adsorption and bio-filtration.

The higher removals obtained under 5.1 cm (2") and 7.6 cm (3") rates of application for BOD, COD, Total P, Ortho P, Organic N and NH_3-N through a medium textured soil system are satisfactory. The removals obtained are in agreement with other land infiltration systems as reported by Parizek, et al (15) Merrell, et al (17) and Temple University (20).

This feasibility study has shown that an application rate of 7.6 cm (3") per week per acre with very high removal efficiencies of nutrients and with no apparent limiting factor can be determined as an optimum application rate for the treatment of fish and vegetable processing lagoon effluent of given quality (Table 1).

SUMMARY AND CONCLUSION

1. During the test period (October 25 to December 5, 1971), fish and vegetable processing lagoon effluent from a plant in southwestern Ontario was successfully treated by spray irrigation on a medium textured land with no crop cover.

2. A spray application rate of 7.6 cm (3") per week per acre of lagoon effluent on a sandy loam soil was determined as the optimum loading rate producing a high quality percolate containing only 14 mg/l BOD, 41 mg/l COD and 5 mg/l NO_3-N on an average.

3. The nutrient removal efficiencies of the soil bio-filtration system at spray application rate of 7.6 cm (3") per week per acre were 96% BOD, 94% COD, 92% Soluble P, 91% Total P, 80% NH_3-N, 86% Organic N, 77% Total N, 65% Organic C and 52% Total Carbon.

4. The total potential of land treatment system could not be fully determined from this preliminary study as the cover crop system could not be included due to very late growing season. It is suggested that a combination of soil and plant system could be highly successful and should be fully investigated over an extended period of time.

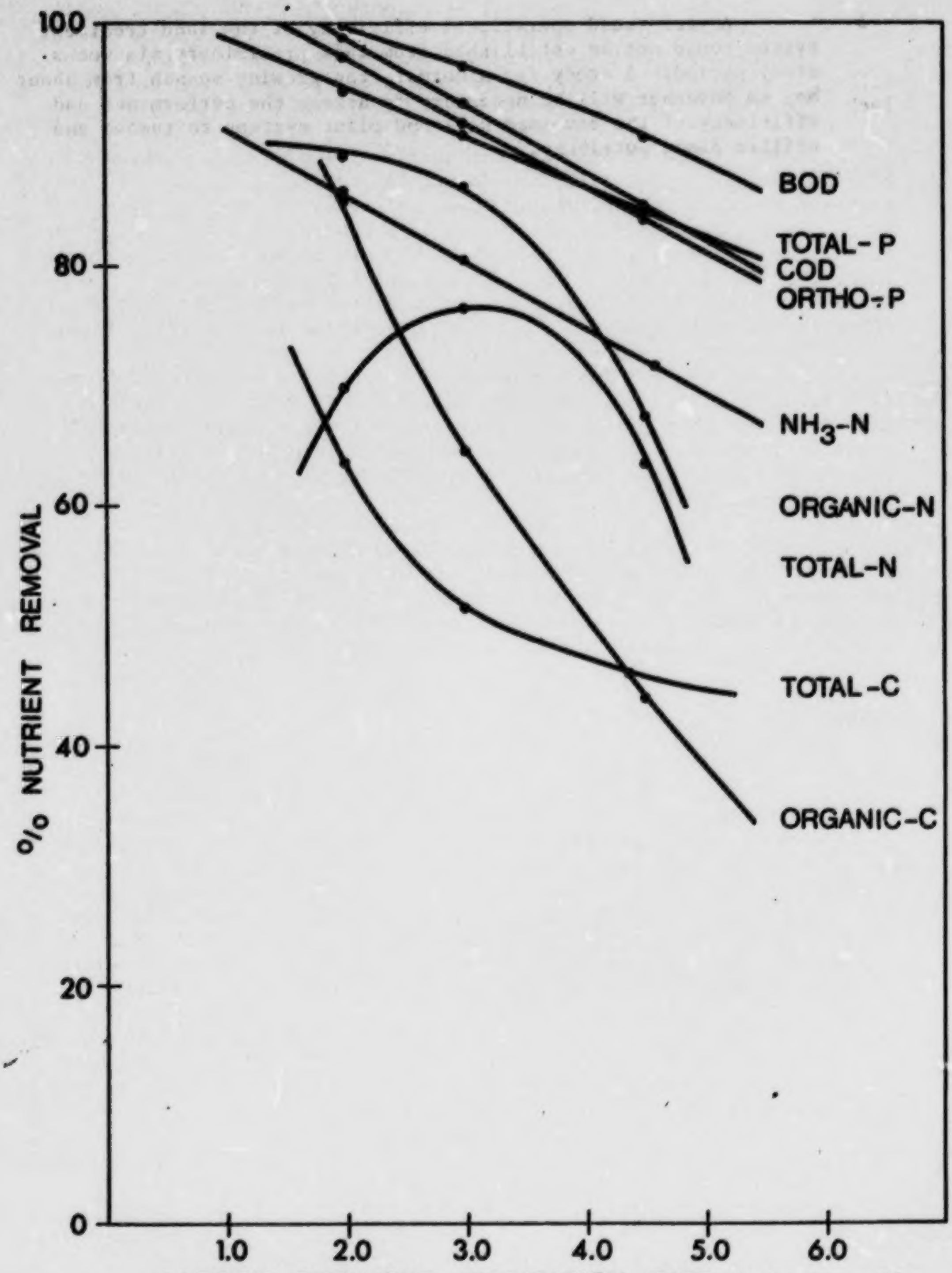

FIG. 3 NUTRIENT REMOVAL EFFICIENCY (%) WITH APPLICATION RATE

5. A year-round operational efficiency of the land treatment system could not be established from this preliminary six weeks study period. A study for a normal crop growing season from about May to November will be necessary to assess the performance and efficiency of the combined soil and plant systems to remove and utilize plant nutrients.

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WATER POLLUTION CONTROL PROBLEMS AND PROGRAMS OF THE MAINE SARDINE COUNCIL

JAMES S. ATWELL,[*] RICHARD E. REED[**] AND BARRY A. PATRIE[***]

I. GENERAL

The Maine Sardine Council was created in 1951 by the State Legislature, at the request of the canners, to finance and administer a comprehensive industry development program. It is a State agency funded through a mandatory tax on the canners of 25¢ a case as produced. Activities include quality control, product promotion at all levels, statistics, government and public relations, biological and technical research and development and a cooperative approach to meet all major industry problems as they occur.

During the early and mid 1950's, the number of canneries averaged about 45 annually. Since that time, because of dwindling fish supplies, foreign competition, consolidations and other factors, the number of active processing operations has dropped to 17 in number. A majority of the plants are old and in most cases located on wharfs over the water.

Atlantic herring are the source of raw material with the fish normally averaging approximately 6 to 8 inches in length and 5 to 8 to a can. Generally it requires approximately one bushel (70 lbs) of fish to produce a standard 100 can (4 oz) case.

As the environmental protection movement blossomed, discharges from the sardine processing plants inevitably came under scrutiny and it was quickly evident that waste water treatment would be required. The primary troublesome component associated with these wastes was the oil and grease generated during the packing process. Organic fish components in the fluming and fish pump waters are rapidly consumed by marine life in the vicinity of processing plants and represent a minimal pollution problem in tidal waters, however their consideration in the overall control program was necessary.

Recognizing the need for technical assistance, the Maine Sardine Council retained the Edward C. Jordan Co., Inc. to identify the wastewater sources and to recommend a pollution control program commensurate with current and anticipated State and Federal guidelines.

Phase I of this program, was undertaken in the fall of 1970. This program involved the establishment of process flow diagrams and waste flow data for each of the active industry operations. As a result water conservation was recommended as an intermediate first step. The

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Phase I report was completed early in 1971. During the spring of 1971, the Council authorized the Jordan Co. to undertake Phase II of the program which included wastewater sampling, flow measurement and analysis at several selected processing plants as well as the evaluation of various potential wastewater treatment systems. An interim Phase II report was submitted to the Council in December, 1971. Since that time, the Council and the Jordan Co. have evaluated various prospective wastewater treatment systems and have worked with the Maine Department of Environmental Protection (formerly the Environmental Improvement Commission) to develop treatment guidelines for the industry. The system selected for use by the Council must take into account the technical and non-technical factors peculiar to the Maine Sardine Industry. These will be discussed later.

II. THE SARDINE PACKING PROCESS

Figure No. 1 shows a schematic process flow diagram for a typical Maine Sardine Packing Plant. Although the process may vary somewhat from plant to plant, it consists of the following steps:

1. Fish Delivery

The fish arrive at the plant by either boat or truck and are pumped and transported to storage tanks by fluming operations. The water used is a combination of the transporting brine and tidal water of varying salinity, and is usually discharged directly back to the nearby tidal water. If the fish arrive by truck, they are either flumed to the packing tables or storage tanks, or a combination flume and conveyor system is used.

2. Storage and Pickling

If the fish are to be stored for any length of time prior to processing, a concentrated brine solution is added to the fish in the storage tanks. This is generally recycled through refrigeration units to maintain low temperatures within the tanks. When the fish are to be processed, the brine is returned to brine storage tanks for reuse, or discharged with the fish.

The fish are removed from the storage tanks by dip nets or hosed into transport systems consisting of fish flumes, conveyors, or a combination of flumes and conveyors. These systems deliver the fish to the cutting and packing tables, which may, or may not, be on the same level as the storage tanks.

3. Cutting and Packing

The fish are cut to size by hand prior to packing. The use of cutting machines for packing fish steaks are used on a limited basis. The cutting and packing tables are generally fed with a continuous supply

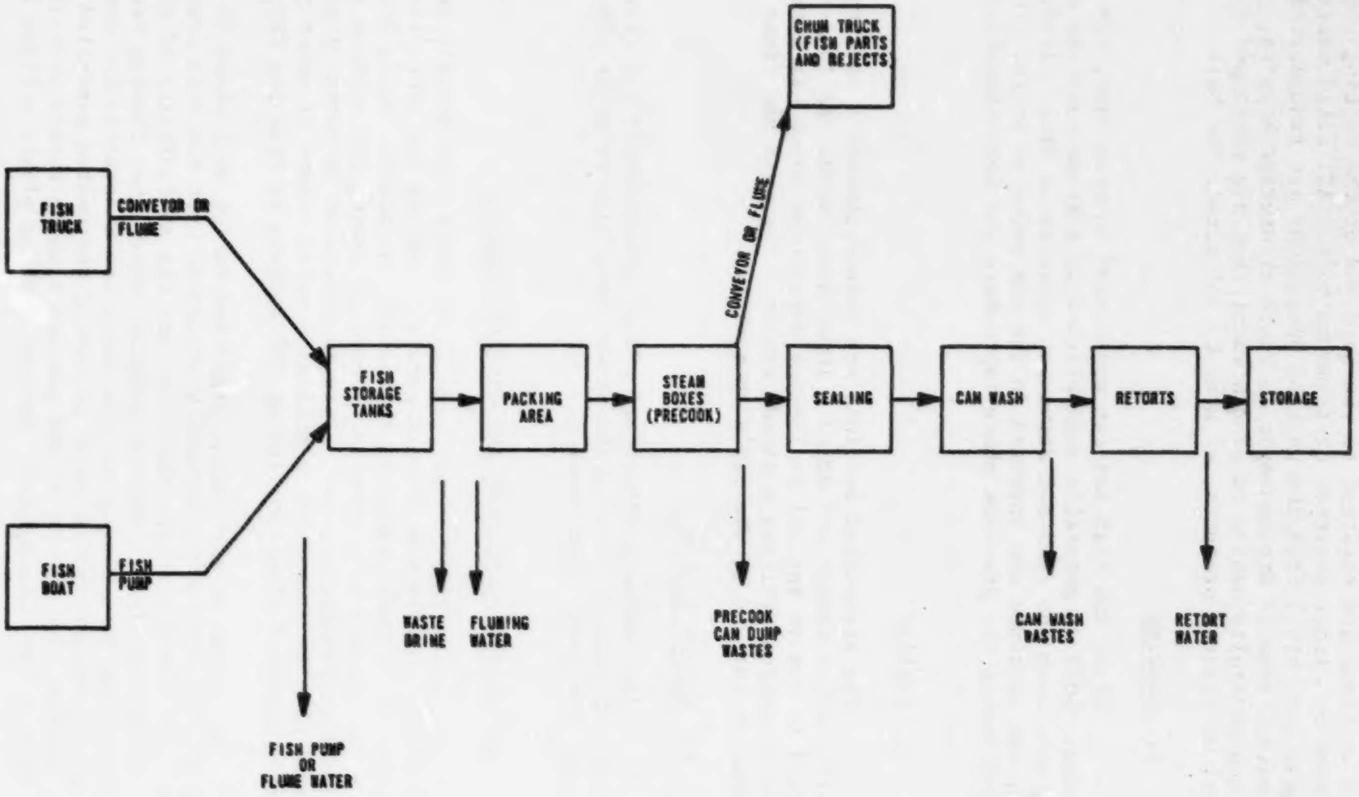
FISH TRUCK
CONVEYOR OR FLUME
FISH BOAT
FISH PUMP
FISH STORAGE TANKS
PACKING AREA
STEAM BOXES (PRECOOK)
SEALING
CAN WASH
RETORTS
STORAGE
CHUM TRUCK (FISH PARTS AND REJECTS)
CONVEYOR OR FLUME
FISH PUMP OR FLUME WATER
WASTE BRINE
FLUMING WATER
PRECOOK CAN DUMP WASTES
CAN WASH WASTES
RETORT WATER

FIGURE NO 1
SCHEMATIC PROCESS FLOW DIAGRAM

7000571U

of fish via conveyor or flume. Fish remaining at the end of the feed conveyor or flume are returned to the head end of the cutting and packing process by either conveyor or flume methods. All solid wastes (head, rejects, etc.) from the packing operations are transported by either water flume or dry conveyor to truck or storage hoppers. These solids are generally hauled to plants where they are processed into fish meal or related products, or used by lobstermen for bait.

4. Cooking

After the fish are cut and placed in open cans, they are pre-cooked. This is generally accomplished in a steam oven and serves to partially cook the fish and drive out undesirable oils. After pre-cooking, the sardines are inverted in the can racks to drain. The waste generated during the pre-cook phase represents the most troublesome component.

5. Sealing

The pre-cooked sardines are passed through a sealing machine where oils and/or sauces are added. Immediately after sealing, the cans are washed to remove any oil or foreign substances which may have collected. The wash operation utilizes a closed system. The wash and rinse waters are dumped at the end of the day's operation.

6. Retort Cooking

The canned sardines are placed into retorts for final cooking. Water is used to cushion the sealed cans as they enter the retorts and to cool the cans after cooking.

III. WASTEWATER QUANTITIES AND CHARACTERISTICS

During the Phase I and Phase II programs, the quantities and characteristics of the wastewaters generated during the processing were established at various canneries throughout the State. Table No. 1 presents the volumes of wastewater generated during the various stages of the sardine packing process. Data is presented in terms of gallons per bushel of fish processed as well as a total volume of water generated, assuming a standard plant processing 700 bushels of fish per day.

The volume of wastewater generated during each phase of the packing process varies significantly depending upon the fish transport methods used, the age of the facility, and the availability of process water. Plants utilizing conveyor methods rather than fluming techniques for transporting fish throughout the plant use substantially less fluming water, which represents the major source of wastewater generated at the packing plants. The source of the process fluming waters contributes to the total water consumption. Several packing plants utilize fresh water from public systems while others utilize large quantities of tidal water. When process water must be purchased, better conservation methods are practiced.

TABLE NO. 1

WASTEWATER QUANTITIES

	Gallons/Bushel		Gallons/Day
	Average	Range	(700 Bushels Processed)
Fish Transport (to storage)			
boat	40	40- 45	28,000
truck	70	40- 90	49,000
Fish Transport (storage to packers)	100	30-250	70,000
Waste Transport (Chum)	35	0-100	24,000
Brine	2.5	1- 8	1,800
Retort	10	5- 15	7,000
Can Wash	4	2- 7	2,800
General Cleanup	1.5	1- 3	1,000
Can Dump	-	.5- 1.0	500
TOTAL	190-220	100-400	135,000-155,000

Table No. 2 shows the characteristics of the wastewater generated during the various stages of the sardine packing process. Average values as well as a range of values found at the various plants are presented. Examination of this data shows that the most concentrated wastewater flows are the pre-cook can dump wastes.

The fluming waters have been divided into three categories: (1) transport of fish from truck or boat to storage; (2) transport of fish from storage to packers; and (3) transport of solid waste to the chum truck. The fluming waters used for the transport of fish to storage often include the brine used for preservation and for this reason are relatively high in BOD_5. The fluming water for transporting the fish from storage to the packing tables is somewhat lower in BOD_5. The chum

TABLE NO. 2
WASTEWATER CHARACTERISTICS (mg/1)

	BOD		COD		Sus. Solids		Oil & Grease
	Avg.	Range	Avg.	Range	Avg.	Range	Avg.
Fish Transport* (storage)	1,000	700- 3,000	3,900	1,000- 7,000	2,300	900- 3,000	-
Fish Transport (Storage to packers)	400	250- 800	900	400- 1,600	450	100- 1,000	120
Waste Transport (Chum)	1,400	850- 3,700	2,000	1,000- 5,000	500	150- 850	440
Retort	50	0- 130	150	20- 350	55	2- 200	15
Can Wash	―――	―――	―――	―――	―――	―――	500
Pre-cook Can Dump	35,000	22,000-50,000	50,000	37,000-75,000	30,000	12,000-60,000	20,000
Overall Outfall	750	650- 1,000	1,850	900- 3,500	600		500

*Overall outfall does not include fish pump wastes flume waters have a rather wide variation in BOD_5 depending upon the volume of water utilized and the size and condition of the fish being processed. It should also be noted that in some instances the tidal waters used for fluming have initial BOD_5 concentrations as high as 50 mg/l. The retort water is very low in BOD_5.

Fortunately, the waters with high waste concentrations have lower volumes, whereas the waters with lower waste concentrations, such as the fluming waters, have significantly higher volumes. Total solids data are not presented since fluming waters may be fresh or tidal. Tidal water has a total solids content of 30,000 to 35,000 mg/l, whereas fresh water, in this area, will have a total solids content of generally under 200 mg/l, depending upon the source. The increased solids are almost entirely made up of dissolved sodium chloride.

The total pollutional load is dependent upon both the strength and volume of the wastewater discharges. Table No. 3 takes this into account and shows the total pollutional load, as measured in pounds of BOD_5 per day, generated by each of the packing processes. As shown in Table No. 3, the largest source of BOD_5, in pounds per day, is the fluming water which represents more than half of the total pollutional load generated. Smaller, but still significant, pollutional discharges eminate from the pre-cook can dump waste and the can wash waters. An average plant will generate approximately 770 pounds of BOD_5 per day when processing 700 bushels of fish or 1.1 #BOD_5/bushel. This figure may range from .75 to 1.5.

TABLE NO. 3

TOTAL WASTE DISCHARGE

SOURCE	POUNDS BOD_5/DAY
Flume Waters	450
Can Wash & Rinse	125
Retort	15
Pre-cook - Can Dump	150
Misc. & General Cleanup	30
	770

IV. EQUIPMENT EVALUATION PROGRAM

The water pollution control problems of the industry are characterized by several unique factors which make it quite difficult to easily accomplish pollution control. Some of these are non-technical, while others are of a technical nature. Some of the problems are as follows:

1. An important factor effecting the pollution control program of the Maine Sardine Industry is the uncertainty relative to the availability of fish suitable for packing. The general trend over the past several years has seen the number of cases of sardines packed decrease significantly. At the present time there is no assurance that this situation will improve in the future. Some scientists and marine experts feel that availability of suitable fish for sardine packing will continue to decrease in the future.

Therefore, as a result of the very uncertain future of the Sardine Packing Industry, there is reluctance by some packers to invest even moderate sums for pollution control even though the Industry is aware of the need to institute pollution control measures.

The equipment evaluated and pollution control measures suggested herein attempt to take into account the uncertain future of the industry by recommending procedures designed to reduce or eliminate the most severe problems and to provide the most practical treatment to the less concentrated waste flows.

2. Sardine processing is a seasonal operation. During the packing season waste flows are intermittent and may vary from 200,000 gallons one day to nearly zero the next. The sardine packing season is relatively short, and during this time, periods of operation are dependent upon the availability of fish.

3. A large quantity of tidal water, high in salinity, is used by a majority of the plants.

4. Conventional biological treatment systems are not suited to treating individual waste flows of the type described above. Properly designed municipal treatment facilities, utilizing such systems, could, however, treat these waste flows if sufficient dilution is provided by the domestic wastes. Since many of the plants are located in rural coastal areas which have little chance of being served by municipal facilities, they must provide their own treatment system. It will be necessary for this system to utilize non-biological treatment processes.

The major efforts of the Council have been directed at developing an acceptable treatment system for those plants without the opportunity of discharging to a municipal system. For those plants located near municipal facilities, however, it will be necessary for each to evaluate the relative mertis of discharging directly to the municipal system, pretreating their wastewater and discharging to the municipal system, or providing their own means of wastewater treatment.

As mentioned earlier, the future of the sardine packing industry is very uncertain, and the necessary expenditure of large sums of money for pollution control poses some very difficult decisions for many of the canners. Therefore, the equipment evaluated had to be capable of treating intermittent waste flows of varying character at a minimum cost.

Based on these restrictive criteria, physical-chemical treatment systems utilizing the principle of air flotation seemed to offer the most potential for meeting these criteria. Air flotation devices from two manufacturers were tested with the results discussed in a following section.

In addition to the air flotation systems various screening mechanisms have been evaluated. The Bauer Hydrasieve offered the most efficient solids removal on combined processing waters. The screen size tested was .040 in..

Circular vibrating screens were tested on sardine packing wastes and found to be relatively ineffective. When screen openings were small enough to effectively remove suspended solids, blinding of the screen occurred. With larger screen openings the unit did not appreciably reduce suspended solids levels.

A Fram Oily-Water-Separator was tested on the pre-cook can dump wastes and was found to be ineffective in reducing the oil concentration. The Fram equipment was unable to break the oil emulsion present in this water.

Stationary Screens

After testing a Bauer Hydrasieve was purchased by a cannery. The initial installation included a 6 foot model with .040" screen openings. The unit was required to screen the entire wastewater flow, but periodic flooding of the unit occurred during peak flows. To minimize this problem a second unit was purchased and installed in parallel with the initial screen. This equipment has been tested several times and has been found to be effective in removing suspended solids. The Hydrasieve has no moving parts, thereby requiring very little maintenance. Table No. 4 shows the data obtained during this testing.

TABLE NO. 4

HYDRASIEVE TEST DATA

	INFLUENT	EFFLUENT	% REDUCTION
BOD_5 (mg/l)	420	360	14%
	820	760	7%
	950	900	5%
Suspended overall effluent solids (mg/l)	1900	1200	37%
	2020	1700	16%
	200	144	28%
	235	180	23%

From this data it can be seen that the Hydrasieve removed 16-37% of the suspended solids and 5-14% of the BOD.

The solids removed consisted primarily of fish scales, viscera and parts of fish. These are collected and hauled to a central processing plant for conversion to fish meal.

Air Flotation Systems

Two air flotation systems have been tested during the processing of sardines. The basic application of this equipment has been in treating the high concentration - low volume wastes, such as the pre-cook can dump, can wash, and general clean up wastes. Although the total volume treated might be only 5000 GPD, these wastes represent approximately 40% of the BOD_5.

Air flotation systems manufactured by Pollution Control Engineering and CE NATCO were tested on the wastes mentioned in the previous paragraph. The results of these tests are shown in Table 5.

TABLE NO. 5

AIR FLOTATION SYSTEMS
(all data in mg/l)

		INFLUENT	EFFLUENT	% REDUCTION
Pollution Control Engineering	BOD	7500	3200	57
		12000	3500	71
	Suspended Solids	6450	530	91
		3550	50	98
	Oil & Grease	1150	230	80
		—	205	—
CE* NATCO	BOD	13300	7400	45
	Suspended Solids	4400	1300	70
	Oil & Grease	—	—	—

*See comments in text

As can be seen from the data in Table No. 5, the PCE air flotation system accomplished BOD and suspended solids reductions in the range anticipated for equipment of this type. The BOD reduction of 60-70% is in the range reported in the literature. The suspended solids removal was somewhat higher than reported, however, a long term testing program may show the removals to be consistently higher than 80%. Oil and grease removal for the PCE air flotation system is shown as 80% with an effluent concentration of over 200 mg/l. During a later testing period, with the polymer dosage optimized, an effluent oil and grease concentration of 26 mg/l was reported.

During this testing of the CE NATCO air flotation system, the unit was not operating at peak efficiency because of a faulty pumping unit. The data is presented for general information only and does not reflect the true efficiency of the unit.

Additional testing will be necessary to accurately assess its treatment efficiency.

Both the PCE and the CE NATCO units had rated capacities of 50 GPM. Desirable operation flows would be on the order of 25-35 GPM. Some form of flow equalization system will be necessary to prevent high flows from reaching the air flotation unit and to assure optimum operation.

Polymer and alum was added to the flows prior to the flotation unit. A polymer dosage of approximately 2 mg/l and an alum dosage of 200 mg/l was utilized during the testing.

V. PROPOSED POLLUTION CONTROL PROGRAM

As a result of this program, basic pollution control recommendations were developed for the sardine industry by the Jordan Co. In addition the Council cooperated with and made recommendations to the Maine Department of Environmental Protection in the development of a State policy on the treatment of wastewaters for the entire Maine fish processing industry. However, several of these recommendations have not been accepted by DEP.

The major initial control efforts of the Sardine Industry, as recommended by the Jordan Co., are to be directed at reducing the wastewater discharges to the greatest extent possible within reasonable economic limits. These efforts include:

> I. The institution of water conservation practices. The reduction of wastewater volumes will have a significant effect on the quantity of the pollutants discharged and will simplify treatment requirements. As mentioned previously, the largest source of wastewater within the packing process is that contributed from the fluming operation. Substantial reduction in water consumption can be accomplished by the installation of dry conveyor methods for fish transport. This fact was dramatically demonstrated at several plants where such equipment was installed.

At one plant tested, the water consumption was reduced from over 300 to approximately 100 gallons per bushel over this period.

II. Separate treatment of all sanitary wastes. These wastes may be treated in a municipal facility, discharged to a standard septic tank and leaching field system, or to a subsurface sand filter with discharge of the effluent to tidal waters.

III. Screening of all fresh and tidal fluming water, including waters from the fish pump. Special consideration may be necessary for chum flume water if present.

IV. Discharge of retort cooling and cushion of water with no treatment.

V. Treatment of can wash, can rinse, general clean up and other miscellaneous wastewaters. These wastes have relatively high quantities of oil and grease, organic matter, and detergents. The objective of this treatment is to reduce contaminant concentrations to levels where they will not have a detrimental effect on the receiving waters.

VI. Precook can dump wastes occur in small volumes and should be collected and discharged to a renderer with the chum waste if possible or treated with the wastes outlined in V.

The pollution control recommendations outlined above are sufficient to meet the interim State policy on the treatment of fish processing wastes and will minimize the effect of the sardine processing wastes on the receiving water.

The interim State policy which is still under review by the industry, includes the following items:

I. Industrial wastewaters containing non-fish components, (e.g. cleaning agents, soybean oil, mustard, etc.), apron and conveyor drippings, floor washings and waters containing heavy concentrations of fish oil, shall be discharged to a municipal treatment system where practical. In locations where such a system is unavailable, the waste must receive the equivalent of secondary treatment oil and grease removal to a level not to exceed 50 mg/1.

II. Uncontaminated cooling and retort water may be discharged without treatment when the quantity and quality have been determined not to violate receiving water classification.

III. Sanitary wastewater shall be connected to a municipal treatment system where possible. In locations where such a system is unavailable, the wastes must be discharged to a subsurface disposal system or receive the equivalent of secondary treatment plus chlorination.

IV. On an interim basis process waters of large volume, including fluming water, and which contain acceptable levels of organic waste only shall receive a minimum of screening so that particles no larger than 0.5 mm (0.02 inch) in diameter are discharged.

V. The above guidelines have been adopted on an interim basis only. The Board of Environmental Protection requires that the fish industry conduct advanced waste studies necessary to provide data needed to establish "Best Practicable Treatment" criteria for the fish industry.

Timetables have been established for implementing the interim policy guidelines and for completing the advanced treatment studies. Construction must be started on all interim pollution control measures by April 30, 1974. Advanced treatment studies must be completed and submitted to the Board by December 31, 1973. Construction of the necessary facilities must be completed and operational by October 1, 1976.

VI. CONCLUSION

By recognizing its commitment to the environment at an early time, the Maine Sardine Council has been able to undertake an orderly water pollution control program which enabled it to assess the total pollution problem, establish treatment criteria, evaluate alternate treatment systems, and ultimately establish control measures that will conform with final State regulations.

The utilization of existing air flotation technology and available screening equipment will enable sardine packing plants to meet the interim State guidelines. Additional evaluation will be required to complete the advanced treatment studies required by the State and to establish "Best Practicable Treatment" criteria as required by State Statute.

FOOD PROCESSING WASTEWATER
MUNICIPAL DISCHARGE OR SEPARATE TREATMENT?

by

Alan F. Hassett* and Richard W. Klippel*

INTRODUCTION

Historically, the food processing industry has used water to transport and wash its products. With increased emphasis on product quality control and process sanitation, the volume of wastewater utilized has exhibited corresponding growth. Recently, large volumes of wastewater have become a liability. The minor cost of discharging process wastewater to a watercourse or municipal sewer has been replaced with the major expense of separate treatment or sewer use surcharges.

Since waste treatment is not a money-making proposition, the processing plant manager may not wish to burden himself with the problem. If this attitude results in a carte-blanche discharge to the municipal sewer, the plant manager may find the sewer use charges more staggering than his previous wastewater problem. The cost of wastewater treatment may result in a production cost difference of several cents per pound of product between competitive brands; a fact which will have a bearing on the longevity of any operation.

Now that ecology has become a household word, articles on industrial pollution are frequently found on newspaper front pages. Whether the publicity is favorable or not depends on the processing plant manager's actions. We hope that this paper may serve to guide each manager's actions in a profitable direction.

FINANCIAL ASPECTS OF JOINING A MUNICIPAL TREATMENT SYSTEM

There are three important phrases to keep in mind when considering the monitary aspects of municipal discharges:

- Cost Sharing

- Sewer Use Surcharge

- Repayment of the Federal Capital Share

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The industrial portions of the new Federal legislation will be reviewed in a later section, and the other phrases are discussed below.

The basic premise of both cost sharing and surcharges is that the industry should pay its fair share of both the capital and operating costs incurred by the municipal wastewater treatment plant. The charges for capital and operating cost shares are generally based on formulas which take account of the industry's flow and amount of contaminants. Therefore, the more wastewater flow, BOD or suspended solids the industry discharges to the sewer the greater its charge for wastewater treatment will be.

From the above paragraphs, it should be clear that if the industry is able to reduce its wastewater flow, or reduce its solids or BOD loading, the municipal treatment charge will be lowered. Obviously, the in-plant costs must be less than the service charge for the practice to be profitable.

In many cases, industrial wastewater pretreatment can be achieved at a lower cost than the municipal surcharge for the service. Facilities designed for industry have a shorter design life than municipal treatment plants and no architectural requirements. The waste streams involved are usually small volume, high strength wastewaters with minimal fluctuations, and can be given physical and even biological roughing treatment for a very small cost.

One financial aspect which should be noted here is that operating dollars and capital dollars have different values to a typical industry. Since an operating cost is charged before taxes, it is equal to a capital cost of approximately twice the dollar value. Therefore, municipal wastewater treatment surcharges must be compared as an operating expense with pretreatment costs as a combination of operating and capital costs. Simple forms of pretreatment are sometimes so efficient that a substantial real-dollar savings can be realized.

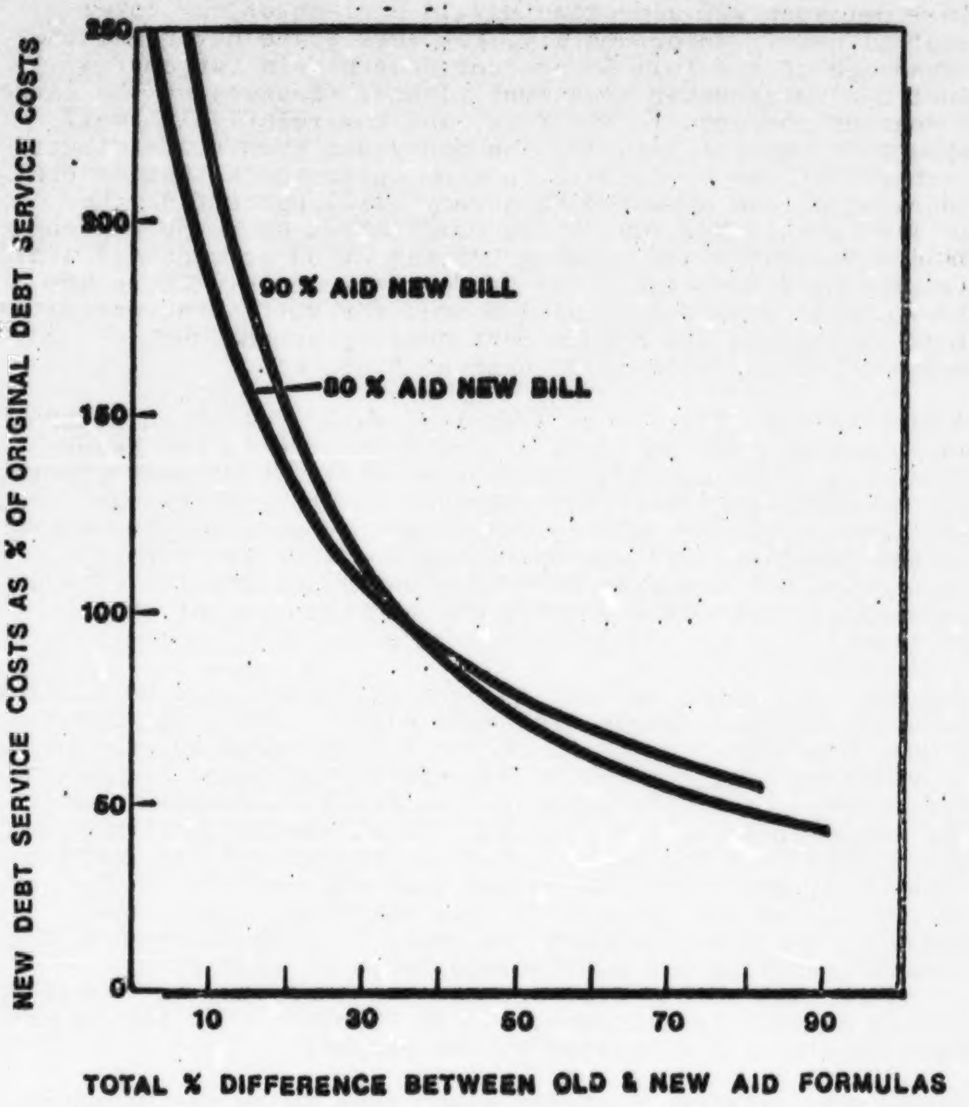
FEDERAL CAPITAL SHARE REPAYMENT

Previous water pollution control legislation; namely, the Water Pollution Control Act of 1966 contained provisions whereby combined treatment plants could be built to treat both municipal and industrial wastes. A total of up to 55 percent Federal construction aid was available in most states for this program. In most cases, industry simply paid their portion of the local capital cost remaining after the Federal and State contributions. This was generally paid from an amortization schedule in yearly payments of both principal and interest. Note that the local share under this legislation amounted to only that portion of the cost remaining after deducting Federal aid of 55 percent, and, in some cases, State aid of 30 percent. Thus, the local share in many cases was approximately 15 percent of the total capital cost. Unfortunately, New York State never had the advantage of the full 55 percent Federal aid for any municipal wastewater treatment plants. Because of the large number of projects in New York, and the relatively small amount of money allocated, the money was evenly distributed over all of the projects. In many cases the actual Federal share allocated amounted to a very small percent of the capital cost. New York State prefinanced up to 30 percent of the Federal share, making a total of 60 percent aid available to most municipalities in New York State. There are many projects on the drawing boards for which cost estimates were calculated using this cost sharing arrangement of 30 percent Federal aid and 30 percent State aid.

Unfortunately, the recently enacted Water Pollution Control Amendment of 1972 provides a drastic change in the Federal financing of combined municipal-industrial treatment plants. The new bill requires that wherever industry discharges to a municipal treatment plant, each industry must pay its share of the local capital and operating costs of the municipal plant; and the industry must also repay its portion of all Federal aid that is given for the construction of the facility.

The new bill proposed that 75 percent Federal aid be allocated to all municipal sewage treatment plants. From all indications, New York State will reduce its aid from 30 percent to 15 percent. So, a total of 90 percent aid might be available for construction of a municipal wastewater treatment plant. For example, under the new bill, if a food processing plant discharged to a municipal treatment system and its combined flow, BOD, and suspended solids load represented a total of 25 percent of the capacity of the municipal plant, that industry would be obligated to repay: 1) 25 percent of the annual operating and maintenance costs of that plant, 2) 25 percent of the debt retirement, including interest, on the 10 percent local share, and 3) 25 percent of the 75 percent Federal aid allocated to the project.

Since many existing projects might have to be re-evaluated under the new aid proposals, we have developed curves (Figure 1) based on the percent construction aid now available and the construction aid percentage for which the project was originally calculated. Assume that a joint treatment plant was originally proposed for a town in New York, and the cost was calculated using 60 percent Federal and State aid under the old bill. The new bill will provide 90 percent aid (75 percent Federal and 15 percent State), which is a percent aid difference of 30 percent (90 percent minus 60 percent). Enter the percent aid difference line of Figure 1 at "30 percent", go vertically to the 90 percent curve, then to the left and read "111 percent". Due to the requirements of the new legislation, the industrial user of this joint treatment will pay 11 percent more in debt service



NOTE: ALL COSTS AMORTIZED AT 6% FOR 30 YRS. CRF = .07265

FIGURE 1 - Changes in Industry Debt Service vs. Percent Difference in Aid Formulas Municipal - Industrial Wastewater Treatment Plants

costs than the original estimate. If the original cost estimate eas calculated using a total of 85 percent aid (55 percent Federal and 30 percent State); the aid difference is only 5 percent (90 percent minus 85 percent), and the industrial user will pay almost three times as much (290 percent of original) for debt service under the new bill.

The relative cost differences shown in Figure 1 were calculated using the assumption that the Federal aid for the industrial portion will be the equivalent of an interest free loan over the life of the project. If, on the other hand, the industry is required to pay back both the principal and interest on a yearly basis, the costs under the new bill would be much higher indeed.

As you can see, the new bill may bring about large changes in cost for any industry that is planning to have their wastes treated in a combined system. Each industry in such a position should keep themselves thoroughly informed of the latest costs and should be well aware of the costs involved in providing their own independent treatment systems. With higher costs for participating in the municipal project, industrial wastewater pretreatment may be more valuable than ever before as a means of lowering industrys' wastewater treatment expenditures.

SPECIFIC EXAMPLES IN THE FOOD PROCESSING INDUSTRY

The examples used in this paper are taken from actual experiences with fruit and vegetable processing operations, but it is felt that the general theme and specific problems apply to the entire food processing field. The high waste treatment surcharges in the industry are due to the nature of the process and product. A typical operation might discharge a large volume of wastewater, high in both soluble organic material and solids. If the processor is located in a rural municipality with a sewer system, the operation is certain to account for a large share of the municipal treatment system. To complete the costly situation, the processor may have a seasonal operation, yet be required to pay for his capital share of the treatment facility on a year-round basis. If the industry accounts for a sizable share of the treatment plant load, the industry may be required to post a performance bond guaranteeing the payment of its entire capital share of the project. It is not uncommon in the food processing industry to find that the amount of the bond required is much greater than the value of all of the company's assets.

To avoid the costly situation described above, the food processor must, of necessity, find a method of reducing his discharge parameters. Specific methods proposed for two separate operations are discussed in detail in the following sections.

Case No. 1 - Cherry Processing Plant - Western New York

This small grower-owned operation processes 3,000 to 4,000 tons of frozen cherries in an annual four week season ranging from mid-July to mid-August. It is located in a village of approximately 5,000 persons in which there are two other food processing industries. The cost of the new proposed wastewater treatment plant will be borne by the three industrial users and the village. The processing operation is generally as follows: cherries are received in truck loads of bushel containers and chilled in cold water tanks; the cherries are then de-stemmed and cleaned; they are colorimetrically inspected, automatically pitted, and finally packaged and quick frozen. This is a relatively simple, efficient, and technologically advanced processing operation. The wastewater is discharged to the municipal sewer and a minimum fee has been charged in the past since only primary waste treatment was provided.

In early 1971, after the village's consulting engineer had taken some samples of all the discharges and prepared his estimate, the Co-op was startled to find that it would be expected to pay roughly 23 percent of the capital cost of the facility, even though it only operated for 30 days or roughly 8 percent of the year. During the 1971 processing season a program of sampling and analysis was conducted at the processing plant. The results showed that even with sizable increases in the amount of products handled, water usage could be reduced while BOD and suspended solids concentrations did not increase measurably.

During the 1972 season, attention was focussed on the wastewater from the pitting operation only. This water is used to carry the cherry pit, after removal, away from the pitting machine. Sample analysis and flow measurement showed that the pitter was responsible for the percentages of the total processing operation shown in Table 1.

The source of this contamination was the de-pitting machine. As the machine's needle pushed each pit through the cherry skin, amounts of juice and flesh escaped attached to the pit. These organic substances were readily solubilized in the effluent flume, and remained in the wastewater after the pits were removed on a shaker screen. Two possibilities seemed available to eliminate the pitter wastewater: either completely dry handling of the cherry pit or complete recycle with an alternate discharge of the transporting liquid on a daily basis.

Table 1. Cherry Processing Wastewater

		Total Effluent	Pitter Effluent	Pitter % of Total
Flow	(gph)	7,850	3,600	46%
BOD	(mg/l)	1,800	2,400	
	(lb/hr)	117.5	72.0	61%
TSS	(mg/l)	128	165	
	(lb/hr)	8.4	4.95	59%
TP	(mg/l)	4.13	7.30	
	(lb/hr)	0.27	0.22	81%
TKN	(mg/l)	25.5	35.4	
	(lb/hr)	1.67	1.06	63%

The equipment manufacturer is presently investigating the possibility of non-waterborne removal of pits from his machine. This would be the ideal way to eliminate this wastewater source; but would mean redesigning the equipment, and is a difficult design problem. In lieu of dry handling, a recycle water system was proposed. By maintaining a low pH and adding an FDA approved bacteriocide, the water could be used in fluming for an entire day's processing. During the regular cleanup period, this sytem would be drained to a pumper tank, and trucked to the landfill. The small amount of liquid (300 gallons) would be sprayed over the cherry pits and then covered.

Costs: The cost of wastewater treatment for total discharge was $385,000 over 30 years or about $12,800/year. Be eliminating the pitter wastewater discharge, the processor's costs are expected to be reduced to $127,000 total, or $4,200/year. This is a reduction of about two-thirds.

The cost of pretreatment has been estimated at $25,000 for the recycle system. Operating costs on the recycle system would amount to about $1,000/year. By installing separate pretreatment on one unit operation, the plant's wastewater treatment costs will be reduced by about 50 percent.

Case No. 2 - Frozen Potato Products Plant - Northern Maine

This frozen foods plant is located in northern Maine in a village of about 1,000 persons. The plant processes 380 tons/day of raw potatoes into frozen french fries and extruded potato products. The company is presently negotiating a contract for joint wastewater treatment with the Village and represents approximately 97 percent of the flow to the proposed treatment plant.

Potatoes are received and stored in the receiving warehouse and then flumed to the processing area. They are steam peeled, washed, trimmed, sliced, sorted, inspected, blanched, french fried, frozen and packaged. The wastewater from these processes originally passed over shaker screens and through an inoperative air flotation tank before discharge to a small tributary of the Aroostook River.

In January of 1972, an intensive sampling program was conducted. Flow and analysis records were compiled on each phase of the process as well as on composite samples of the final effluent. At this time, the process wastewater averaged 750 gpm (~1 MGD) and contained 18,900 pounds/day BOD and 16,200 pounds/day suspended solids. A proposed additional process was expected to add another 100 gpm with 4,700 pounds/day BOD and 2,800 pounds/day suspended solids.

Under these conditions, the proposed municipal-industrial wastewater treatment plant would receive about 1.3 MGD with a BOD concentration of about 2,000 mg/l. After the required 90 percent removal, the treatment plant effluent would retain 200 mg/l of BOD, or about the equivalent oxygen demand of raw domestic sewage. Every reduction achieved in the industry's wastewater would reduce the pollutional load on the stream, as well as lower the industry's percentage of a smaller treatment facility.

Process Pretreatment: Below, each phase of the process is analyzed and the proposed solutions are discussed. While the joint treatment facility has not been approved as yet, some of these measures have been instituted at the processing plant.

Flume Water: The flume water transported potatoes from the storage facilities to the peeling units. At the time of the survey, this operation was using 50 percent recycled water and still discharging 75 gpm of effluent to the plant sewer. The heavy silt load averaged 7,000 mg/l of suspended solids, but the BOD content was only 110 mg/l. Bench scale tests showed that the silt settled quickly when 1 mg/l of an anionic polymer was added. Proposed treatment of the flume water was: silt removal by gravity, with polymer addition, in the air flotation unit after conversion to a gravity settling unit. The effluent, which is low in soluble BOD, would then be of better quality than the municipal effluent and would, therefore, receive only chlorination before discharge. The silt would be dewatered and returned to the farmers as topsoil replenisher.

Steam Peelers: These units had two liquid discharges; one was strictly cooling water, the other was mostly peels which were flushed to a sewer. The cooling water will be segregated as a "clean water" flow, and in combination with the other "clean water" discharges receive only chlorination before discharge. "Clean water" flows were defined as process wastewater in-plant discharges which had a BOD less than 150 mg/l and removable solids. This wastewater (with solids removed) would be of better quality than the municipal plant effluent. Therefore, only disinfection was proposed as treatment. Although no accurate amount could be calculated, it was felt that the turbulent mixing of potato peels and warm water would result in the solubilization of starches and protein and cause an increase in the effluent BOD. Therefore, it was proposed that the peels be separated from the liquid phase immediately, and removed in hoppers to a holding facility from which all the solid potato waste is taken to a processor for use as cattle feed.

Slicers: These three units which cut the potatoes into french fries discharge from 90-100 gpm each with 4,800 mg/l BOD and 39,000 mg/l suspended solids. This process was the worst offender in the plant; contributing about two-thirds of the total daily BOD discharge. This also happened to be the least-cost pretreatment process. The starch in the cutter water caused the extremely high BOD and suspended solids concentrations. One dry-weight pound of potato starch is equivalent of 0.4-0.6 pounds of BOD. By removing 2-3,000 pounds of starch per day in centrifugal hydrocyclones, the processors reduced the total effluent BOD by about 1,500 pounds/day, and made a slight profit on the sale of the starch.

Inspection Table: At this station, the raw, sliced potatoes were inspected for size and blemishes. Any which were too short or had blemishes were placed in a trough of flowing water for transport to the extruded by-product line. This process used 70 gpm of clean water which accumulated 25 mg/l BOD before being discharged to the sewers. In the proposed plan this stream has been segregated as one of the "clean water" flows and will receive only chlorination at the municipal plant.

The rest of the wastewater generated at various processing operations totaled about 200 gpm. None of these streams afforded possibilities for effective pretreatment.

Combined Final Effluent: The study showed that with implementation of the pretreatment discussed above, the potato plant effluent could be reduced from 850 gpm, 23,600 pounds/day and 19,000 pounds/day suspended solids to 580 gpm, 18,200 pounds/day BOD and 7,000 pounds/day suspended solids. The final form of total effluent pretreatment was to remove gross solids with hydrosieves, coagulate remaining suspended solids with food-grade polymer, remove these solids in hydrocyclones, and discharge the solids directly to the solids holding facilities. This operation would remove 30-40 percent of the remaining BOD, and would reduce suspended solids to about 100 mg/l. The final effluent after pretreatment would be 580 gpm, 10,900 pounds/day BOD, and 700 pounds/day suspended solids. The schematic diagrams of the pretreatment systems are shown in Figure 2 (before) and Figure 3 (after).

Costs: The annual charge for the original discharge was $127,000. The combined cost of the pretreatment measures and the reduced municipal surcharge totaled $114,300/year. This amounted to a total project savings of about $3,700 under the 1972 aid policies. According to our curves on the ratio of old to new bill costs, under the present aid policies, the pretreatment system will save the plant about $1.1 million, over the life of the project.

Suggested Method of Investigation

A problem can only be solved after you have discovered the source of the problem. To adequately assess the possibilities for pretreatment in any processing operation, the characteristics of each process discharge within the plant should be known. This includes: flow rate, amounts of contaminants, and the variability of each.

When the major problems are located, the Engineer and Plant Manager can decide what solutions may exist. Possible solutions will be discarded if they do not meet the criteria of process efficiency and sanitation, and effective waste management practice.

The solutions should then be evaluated against the cost of municipal treatment. If the pretreatment is less expensive than the municipal surcharge it should be instituted. This is the time to remember the difference between operating and capital cost dollars!

After the cost comparison is complete, the plant manager will have to decide whether the savings are worth the responsibility of wastewater treatment. At this point he should have the facts necessary to make a profitable decision.

Summary

Pretreatment of food processing wastewater has always been an effective method of reducing the total cost of industrial wastewater treatment in a joint municipal-industrial treatment situation. Now that user charges will include the added burden of the industrial Federal repayment costs, pretreatment will be even more valuable in order to maintain low wastewater treatment costs. Each processing plant manager should thoroughly study his particular situation, and investigate the opportunities for pretreatment before committing the financial fate of his operation to total municipal discharge.

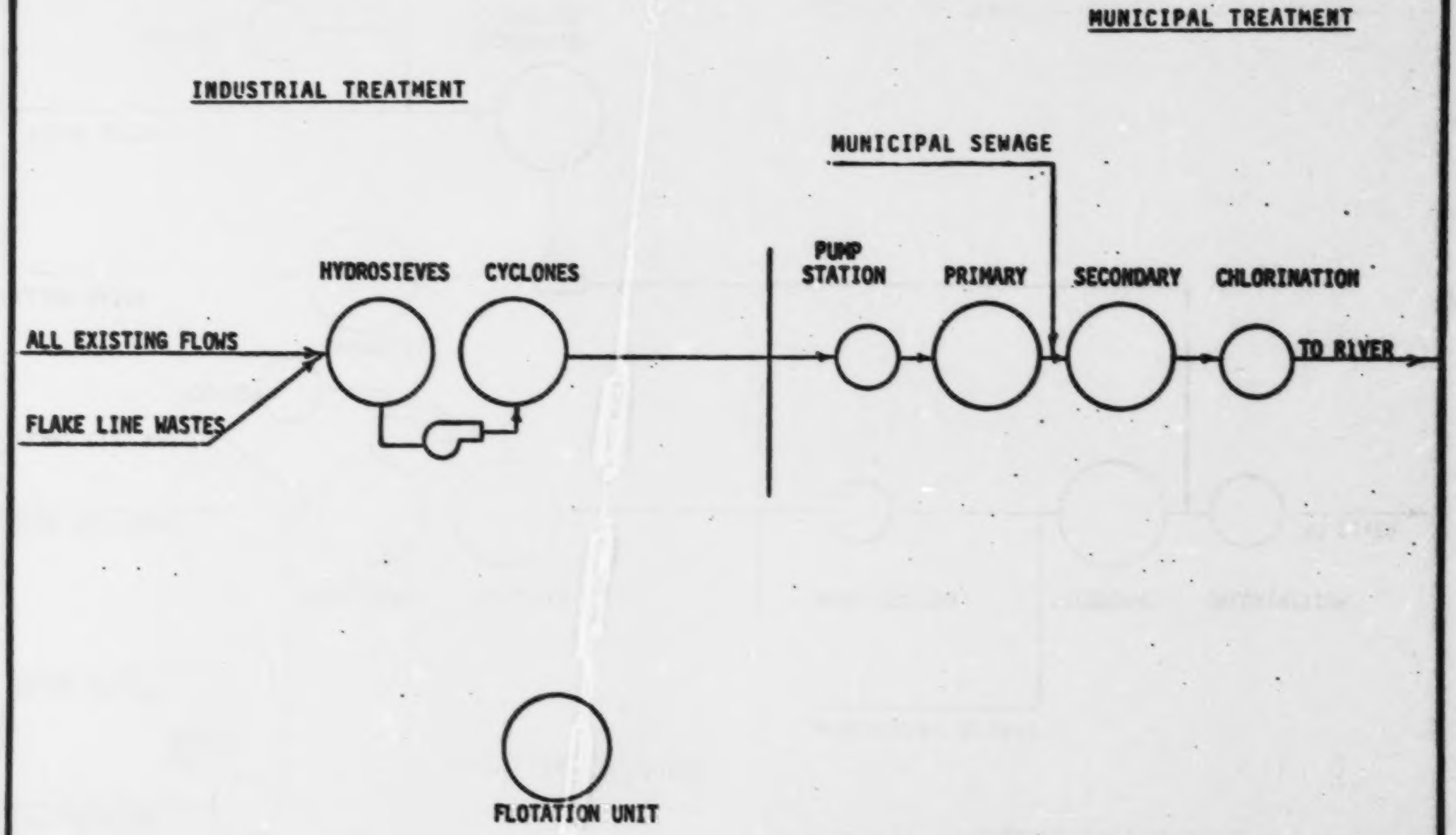

MUNICIPAL TREATMENT
INDUSTRIAL TREATMENT
MUNICIPAL SEWAGE
HYDROSIEVES
CYCLONES
PUMP STATION
PRIMARY
SECONDARY
CHLORINATION
ALL EXISTING FLOWS
FLAKE LINE WASTES
TO RIVER
FLOTATION UNIT

FIGURE 2 - Treatment Schematic prior to pre-treatment measures.

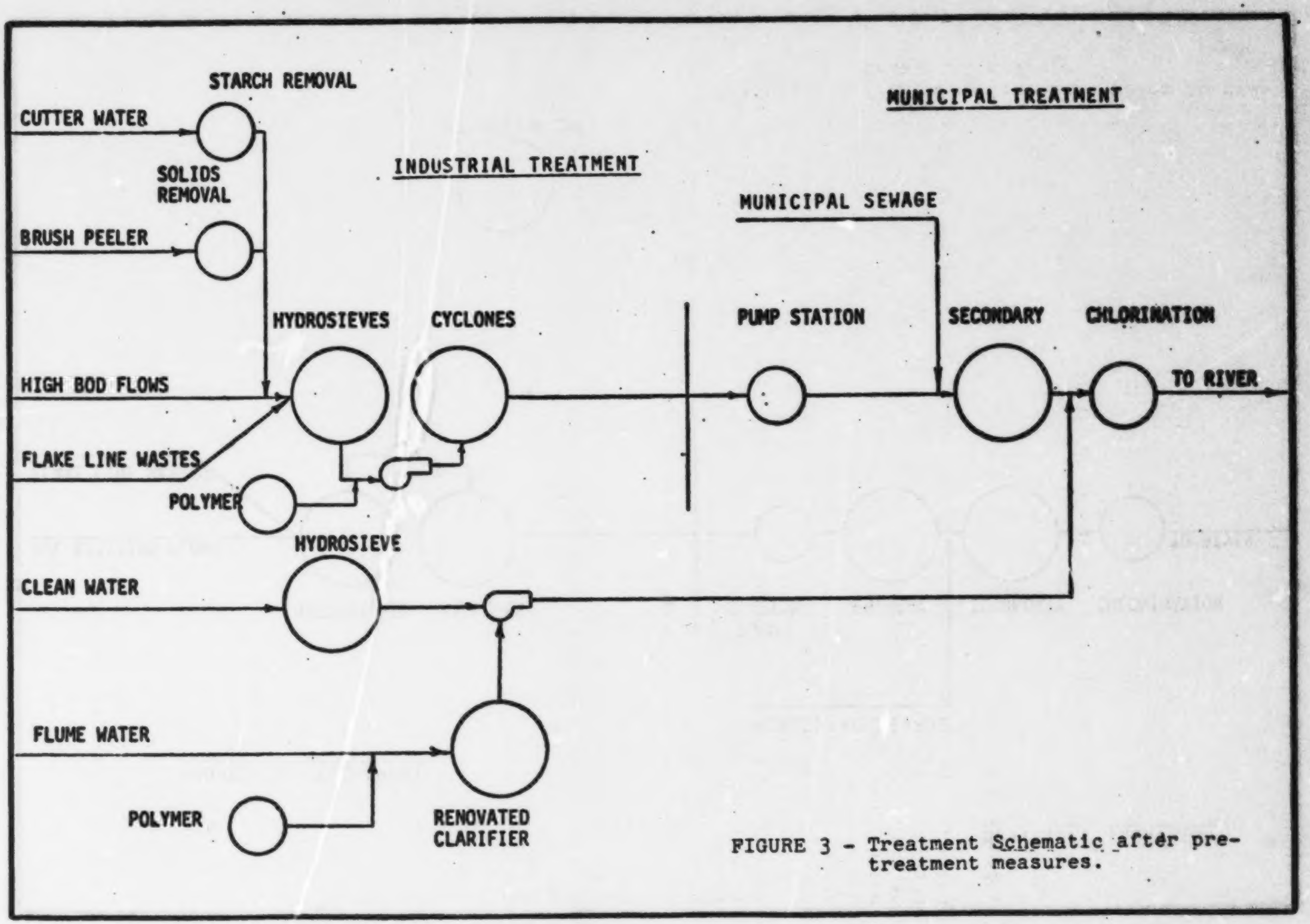

STARCH REMOVAL
MUNICIPAL TREATMENT
CUTTER WATER
SOLIDS REMOVAL
INDUSTRIAL TREATMENT
MUNICIPAL SEWAGE
BRUSH PEELER
HYDROSIEVES
CYCLONES
PUMP STATION
SECONDARY
CHLORINATION
HIGH BOD FLOWS
TO RIVER
FLAKE LINE WASTES
POLYMER
HYDROSIEVE
CLEAN WATER
FLUME WATER
POLYMER
RENOVATED CLARIFIER

FIGURE 3 - Treatment Schematic after pre-treatment measures.

PROTEIN PRODUCTION FROM ACID WHEY VIA FERMENTATION**

by

Dr. Sheldon Bernstein* and Dr. Thomas C. Everson*

INTRODUCTION

Currently the cheese industry in the United States is producing approximately 25 billion pounds of liquid whey annually. As recently as 1970, it was estimated that only about one-third to one-half of the whey produced was utilized (Webb) (1). During the last few years, this utilization has increased, but so has the production of cheese. For each pound of cheese produced, one obtains approximately nine pounds of whey. In 1971, the last year for which statistics are available, 679 million pounds of dry whey were made (319 million pounds for human consumption and 360 million pounds for animal feed.) Other amounts of whey were converted to lactose, whey blends, protein fractions, etc., but if it is realized that the 25 billion pounds of whey previously mentioned represents approximately 1.5 billion pounds of whey solids, it is easily seen that a tremendous amount of this material is not being used.

Whey is the serum of milk resulting form the removal of fat and casein from white milk during the cheese-making process. It is a greenish-yellow liquid containing approximately 6 to 6.5 percent solids and most of the water soluble vitamins and minerals of the whole milk from which it was derived. A typical analysis of the whey solids would be: lactose 68-72%, protein 12-13%, minerals 8-9% plus small amounts of fat and lactic acid. Practically all of the whey produced in this country is of two general types: low acid (sweet whey) from Cheddar, Swiss or Italian cheeses and high acid (acid whey) from cottage or cream cheese.

The problem of disposing or utilizing whey is compounded by a number of factors. The material is 93.5 to 94% water, which makes hauling any distance extremely expensive. It is perishable and will spoil easily so one cannot store it any length of time. To evaporate and dry it, requires a large capital investment and the market for dried whey is such that one just about recovers the cost of processing. Also, acid whey is extremely difficult to dry at all and it can only be done with specialized equipment. Nevertheless, this may be cheaper than trying to dispose of the liquid. The BOD of raw whey is about 30,000-50,000 ppm and since it is not unusual for a cheese plant to produce 500,000 to

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** This investigation was partially supported with funds from the Environmental Protection Agency, Office of Research and Monitoring under Grant number S-800747.

1,000,00 pounds a day of whey, it would require a large disposal or treatment plant to handle this volume. One possible partial solution of this problem would be to convert the lactose in the whey to protein via fermentation in a central processing plant. The demand for protein materials for the feed and food industry is increasing dramatically. Amber Laboratories, with the aid of a demonstration grant from the E.P.A. has studied this possibility by operating a pilot plant facility during the past year.

The fermentation of whey by various microorganisms has been studied by numerous investigators. An excellent review of the work to date appeared in 1970 by Marth (2). Many organisms have been used, but the most promising are the yeasts. Theoretically, the fermentation is relatively simple. Live yeast is added to whey and suitable growth conditions are established. Nitrogen and other growth factors must be supplied along with a large quantity of air, and pH and temperature are controlled. As the process continues, the yeast grows, consuming the lactose and converting it to single cell protein. Eventually the fermentation is complete, all the lactose is used, and the yeast is harvested and dried. This process is the basis of some material produced commercially but in relatively small amounts. (Mayer, B.F. (3).

The purpose of the study reported here, was to see if, by utilizing modern fermentation technology and equipment, a practical, large scale process of producing single cell protein, using the lactose of whey as the carbon source, could be evolved that would be commercially feasible. Providing this objective could be met, it would present one method of utilizing very large amounts of whey, a potential environmental contaminant, and converting it to a useful product which could be used by an industry capable of absorbing the large amounts of material produced (animal feed industry). The results so far are extremely promising.

EXPERIMENTAL

The investigation began by screening a number of organisms via shake flask experiments. These included Torula lactosa (2 strains), Saccharomyces lactis (2 strains) and Saccharomyces fragilis (4 strains). Pure cultures were used and the experiments were so designed to demonstrate the complete utilization of the lactose in whey as well as the rate of fermentation, yield, necessary additional growth factors needed and type of product produced.

From the results of this preliminary work, two strains of yeast (one each of Saccharomyces lactis and Saccharomyces fragilis) were selected for more detailed study in small pilot fermentation vessels. This equipment included a bank of nine 15 gallon (44 liter) fermentors of the jacketed type equipped with automatic pH, antifoam, temperature and nutrient feed controls. They were aerated by compressed sterile air entering thru a bottom sparger and agitated by standard shaft and turbine impeller system. Steam could be directly injected into the vessel or circulated thru the jacket which also carries cooling water. The vessels were fitted with various inoculating and sampling parts and could be fitted to handle oxygen or carbon dioxide sensors. The studies in these fermentors, the details of which will not be discussed at this time and will be reported elsewhere, were conducted to determine various factors to be used in the larger scale studies. Among them were: selection of organism; size of inoculum; sterility conditions; composition of medium; speed of fermentation; temperature, pH, and air optimum conditions; yield of product, feasibility of simi-continuous or continuous fermentation as opposed to batch operation.

The results of these studies showed that the organism of choice for whey fermentation was a strain of Saccharomyces fragilis. This confirmed the work of others (Myers and Weisberg (4); Stimpson and Young (5), Wasserman (6) and Amundson (7). The conversion of lactose into yeast cellular material was efficient, and in the range of 45-55% under non-sterile conditions (55% conversion is close to theoretical). Further, the process was demonstrated to be complete in an 8 hour cycle time and could be operated with a minimum fermentor "downtime" in a semi-continuous manner or without fermentor "downtime" as a continuous fermentation process. Cell yields were approximately equivalent in the batch, semi-continuous or continuous operation. Products obtained had "as is" protein values from 25-55% dependent on fermentation conditions and degree of processing. Standard operating conditions for larger scale work were determined.

The next step was to utilize the above information to operate a 500 gallon fermentor for extended periods of time to study the application of this process to a commercial large-scale operation; to obtain cost data; and to produce enough product for analysis and economic evaluation.

Throughout this study, acid whey was used to prepare the media for the fermentations. This whey, derived from the manufacture of cottage or cream cheese is difficult to dry and often offers greater problems in disposal than sweet whey. However, experiments have shown that the fermentation proceeds equally as well with sweet whey. The organisms utilize lactose as their carbon source and do not distinguish its origin.

Acid whey was obtained in concentrated form (45-50% solids) from cream cheese manufacture. This was diluted with tap water to the appropriate lactose concentration. Other medium additions include: NH_4OH (0.13-0.9%) as the primary exogenous nitrogen source; 0.5% H_3PO_4; yeast extract (0.3% Amber BYF Series 100) and sufficient 30% HCl acid to adjust pH to 4.5. The medium was heated to 80°C for 45 minutes and then cooled. In later studies, referred to as "closed-loop" operation and which will be described later, condensate water was substituted for tap water to dilute the whey concentrate.

A 500 gallon, fully baffled, deep tank stainless steel fermentor with a height to diameter ratio of 1.65:1, was used for these studies, whether batch, semi-continuous or continuous. The media were aerated by compressed air entering through a bottom sparger and agitated by a standard shaft and turbine impeller system. Constant temperature (30° ± 2°C) control was maintained by circulation of water (and/or steam) through the jacket of the fermentor. The vessel was equipped with pH and foam control accessories.

Three 15-liter New Brunswick glass jar fermentors served as seed vessels for the 500 gallon tank. These were standard manufacture and contained air, agitation and temperature control.

Inoculum for the 500 gallon fermentor was prepared by starting with a pure culture on an agar slant and moving successively through 250 milliliter shake flasks, 15-liter fermentors, 60 gallon seed fermentation to 300 gallon working volume in the 500 gallon vessel. An overall schematic of the fermentation process may be seen in Figure 1.

RESULTS

In order to have a reasonable fermentation on a commercial scale, the seed should be of the order of 10-20% of the fermentor volume and the fermentation should be rapid. In batch experiments, this was found to be the case. Starting with such a seed with a viable cell count of 1 x 10^9 cells per milliliter and an inoculum level of 10%, the fermentation under our conditions would be complete (i.e., all the lactose utilized) in 6 to 8 hours with an increase of cell concentration of 10-20 fold. This represents generation time of 2.0 hours and four doublings within an eight hour period.

The semi-continuous fermentations were made by drawing off 90% of the fermentation broth and using the 10% remaining to seed the next fermentation batch. A number of consecutive draw-down batches were run in this manner and the results are shown in Figure 2. In these experiments, it can be seen that the initial cell concentration is about 1 x 10^8 cells per milliliter. After 8 hours of operation, this increases to over 1 x 10^9, a tenfold increase. Drawing off 90% of the fermented mixture and adding fresh medium, dilutes the count by a factor of 10 to 1 x 10^8 cells per milliliter and the process is repeated. As the fermentation proceeds and the cells increase, the lactose of the medium decreases. The data in Figure 2 shows a series of six such consecutive runs. The only "down-time" from such a procedure is the time it takes to pump off 90% of the fermented broth and to pump in fresh medium.

This "down-time" can be eliminated if the fermentation could be run continuously, i.e., with continuous addition of fresh medium and removal of the fermented mass. The most efficient industrial fermentations are of this type. This proved to be applicable in our yeast-whey fermentation.

The continuous fermentation was begun when the cell count in the fermentation broth reached 1 x 10^9 cells per milliliter and the lactose concentration 0.05-0.75% (w/v). At that time, fresh medium was added and fermented whey mass removed at a rate of 37 gallons per hour which corresponded to a batch fermentation cycle of 300 gallons per 8 hours. The results of one such operation is shown in Figure 3. This fermentation was run for 59 hours. The cell count was maintained between 1.2 x 10^9 and 2.4 x 10^9 cells per milliliter and the lactose concentration below 1% (w/v). In Figure 4, a similar fermentation was run continuously for over nine days (220 hours) with the same results. In all runs, there was no indication of any contamination even over these extended periods of time, and no indication of the build-up of any toxic metabolic products that would interfere with the fermentation.

The production of Saccharomyces fragilis on whey is being done in the United States (3) on a small scale and is approved by the FDA for use in feeds and foods (8). The entire fermented whey material (FWM) could be used as a feed ingredient. This would simplify the processing for

FIGURE 1

SCHEMATIC FOR WHEY FERMENTATION PROCESS

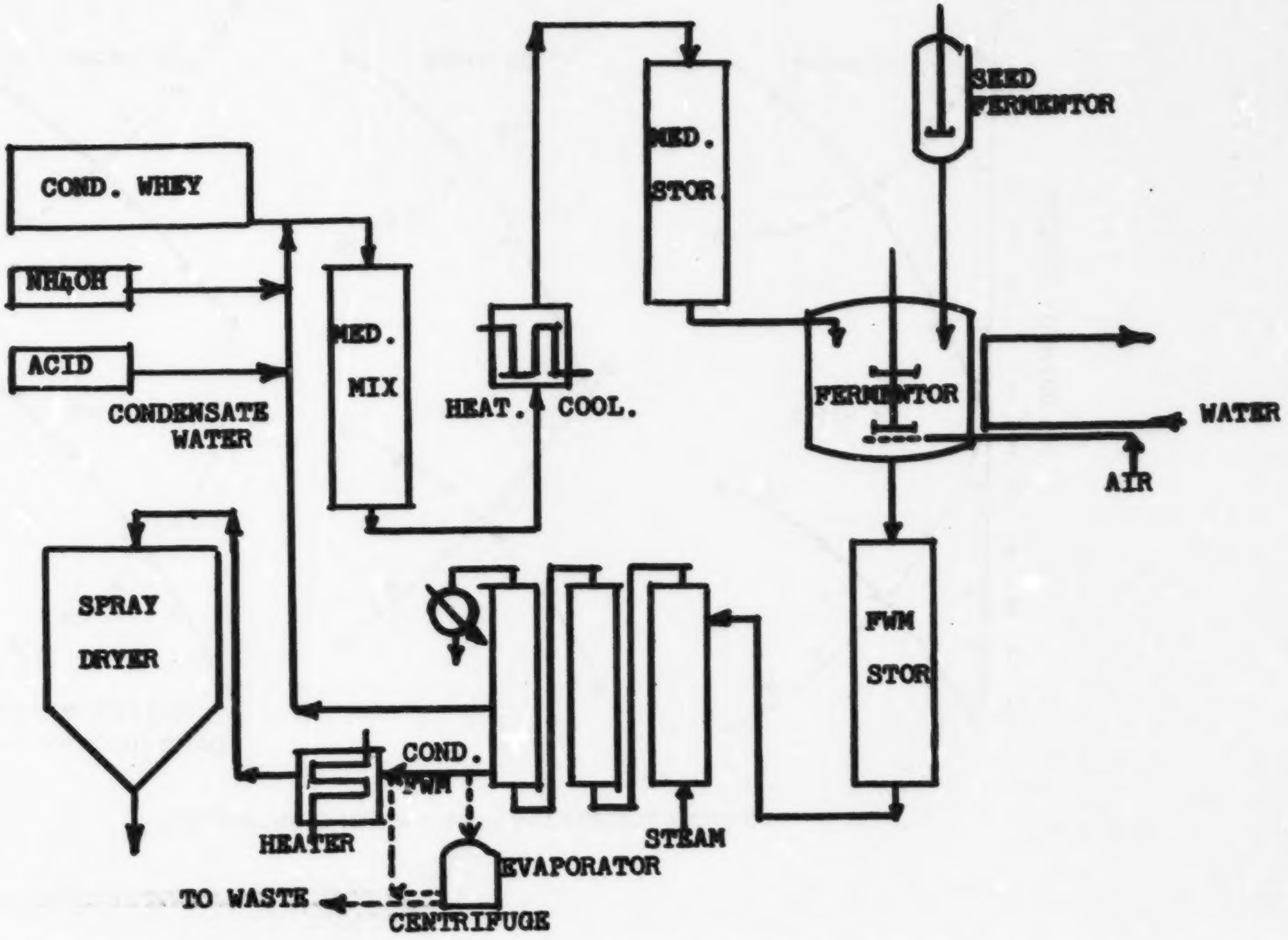

COND. WHEY
NH_4OH
ACID
CONDENSATE WATER
MED. MIX
HEAT.
COOL.
MED. STOR.
SEED FERMENTOR
FERMENTOR
WATER
AIR
FWM STOR
STEAM
EVAPORATOR
COND. FWM
HEATER
CENTRIFUGE
TO WASTE
SPRAY DRYER

FIGURE 2

SEMI-CONTINUOUS FERMENTATION - SACCHAROMYCES FRAGILIS

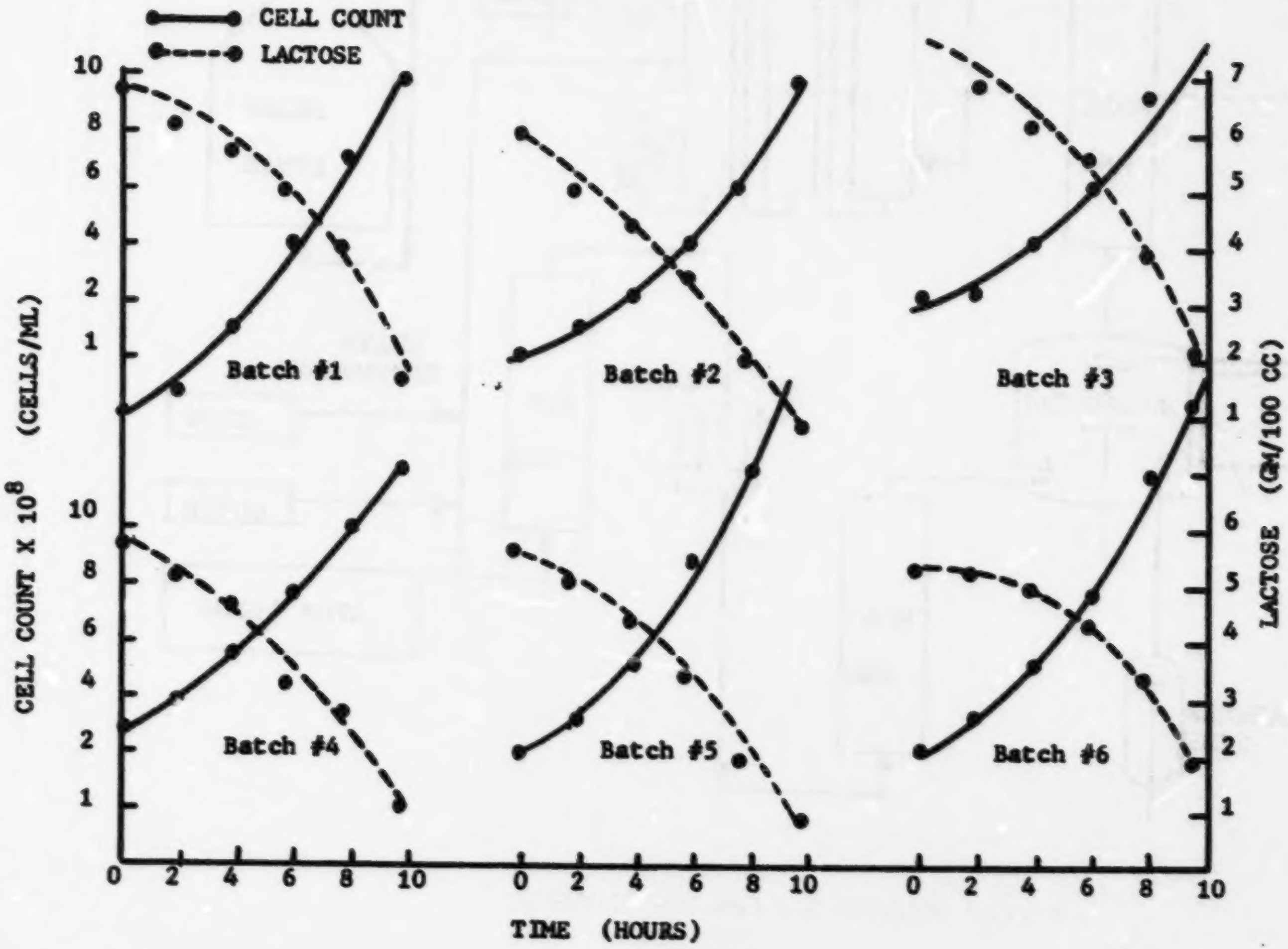


FIGURE 3

CONTINUOUS FERMENTATION - SACCHAROMYCES FRAGILIS - 59 HOURS

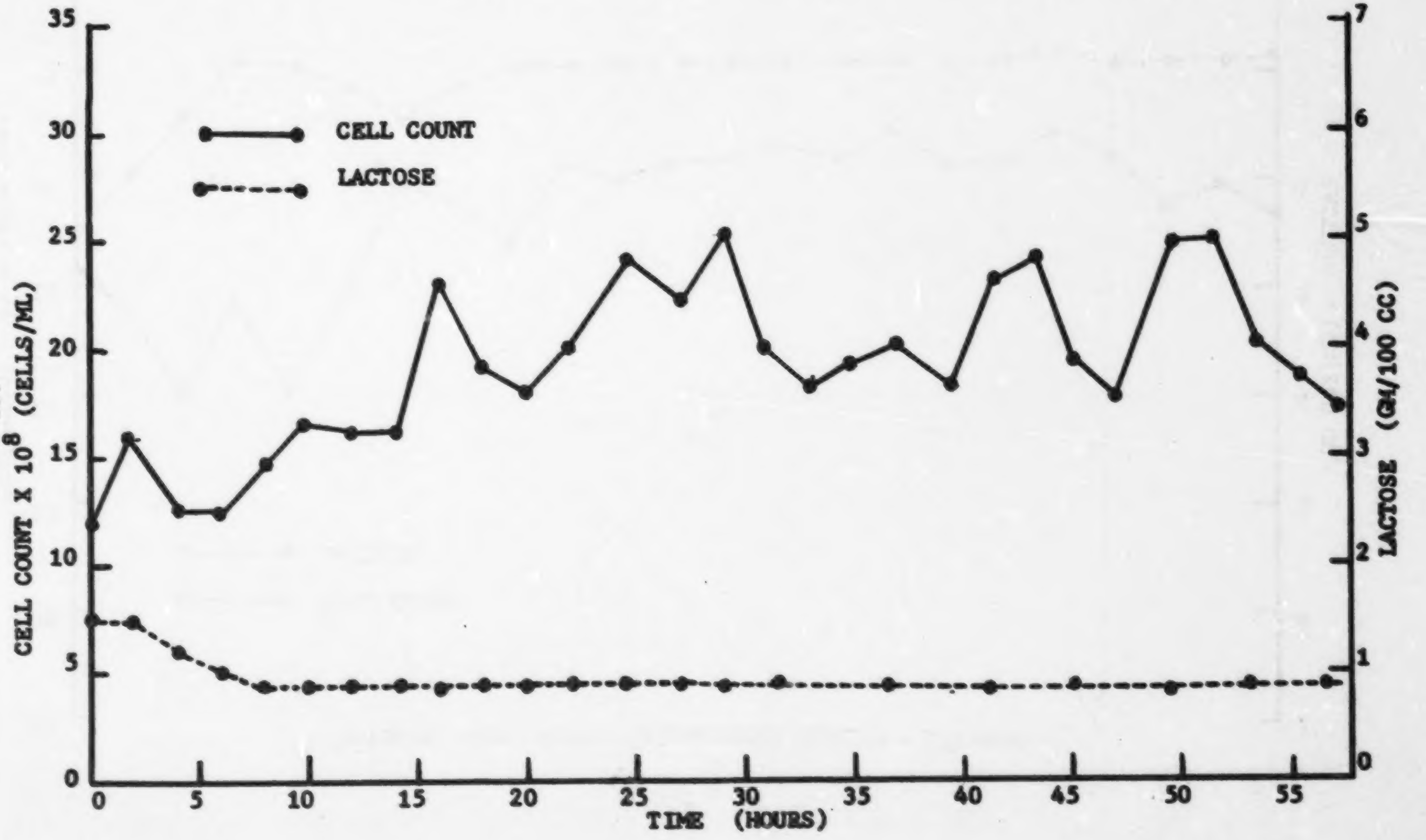
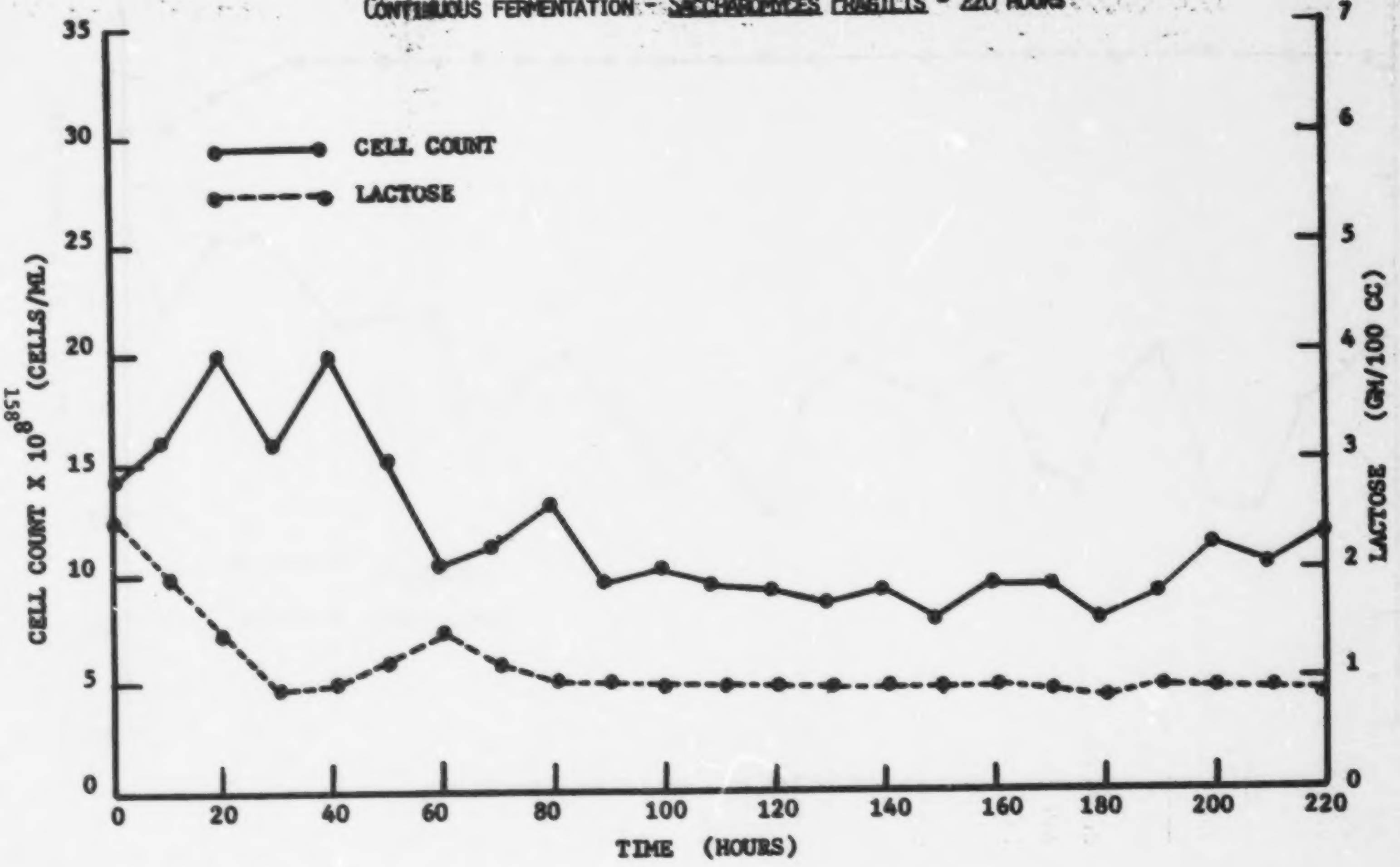


FIGURE 4

CONTINUOUS FERMENTATION - SACCHAROMYCES FRAGILIS - 220 HOURS



it entails only the concentration of the fermentation broth and spray drying. If the FWM is centrifuged before drying, a product is obtained that has a lower ash and higher protein. Finally, if the centrifuged FWM is washed with water and recentrifuged and dried, a third product suitable for use in food is obtained. The proximate analysis of these products are shown in Table 1.

Table 1. Proximate Analysis of Fermented Whey Products

	FWM	Centrifuged FWM	Washed FWM
Crude Protein	32-40%	42-50%	45-55%
Ash	15-20%	8-11%	5- 7%
Fat	2- 3%	2%	-
Moisture	3- 4%	3- 4%	3- 4%

The use of these products as an animal feed and the quality of the protein they contain are shown in Figure 5 and Table 2. Protein Efficiency Ratios (PER) were determined in rat feeding tests (9). In Figure 5, rat growth rates using FWM and centrifuged FWM as the sole protein source in the diet were compared with those using a casein standards. No evidence of toxicity was noted during this period of time. From these experiments, PER values were calculated and tabulated in Table 2. Actual feeding experiments with other animals must be conducted to determine specific values. Very preliminary work with calves and pigs looks promising. The quality of the protein produced by this production of Saccharomyces fragilis on whey is indicated by amino acid analysis. (Table 3.). The amino acid composition of this yeast used in feeds and foods (Brewers yeast and Torula yeast) and to one produced by the fermentation of Hydrocarbons (Petro-protein).(12) The standard amino acid FAO profile is also listed for comparison. All the yeast proteins are high in Lysine and Threonine and low in Methionine.

In an effort to minimize waste streams from the fermentation operation, a "closed-loop" operation was designed. In this process, the concentrated acid whey was diluted with the condensate water derived from the evaporation of fermentation broths, and this was followed by the fermentation of the whey. Theoretically, this closed-loop could be repeated as often as new whey concentrate was added to the cycle (Figure 6). Since the entire condensed fermentation broth was spray dried, no waste streams were obtained. The fermentation results did not differ significantly whether tap water or condensate water was used to dilute the incoming whey. The process was run over extended periods of time with no apparent build-up of any metabolic toxic materials to inhibit the fermentation. In the overall schematic shown in Figure 1, one can see the return of the condensate water to the medium mixing tank.

FIGURE 5

RAT GROWTH RATES
ON CASEIN AND FERMENTED WHEY PRODUCTS

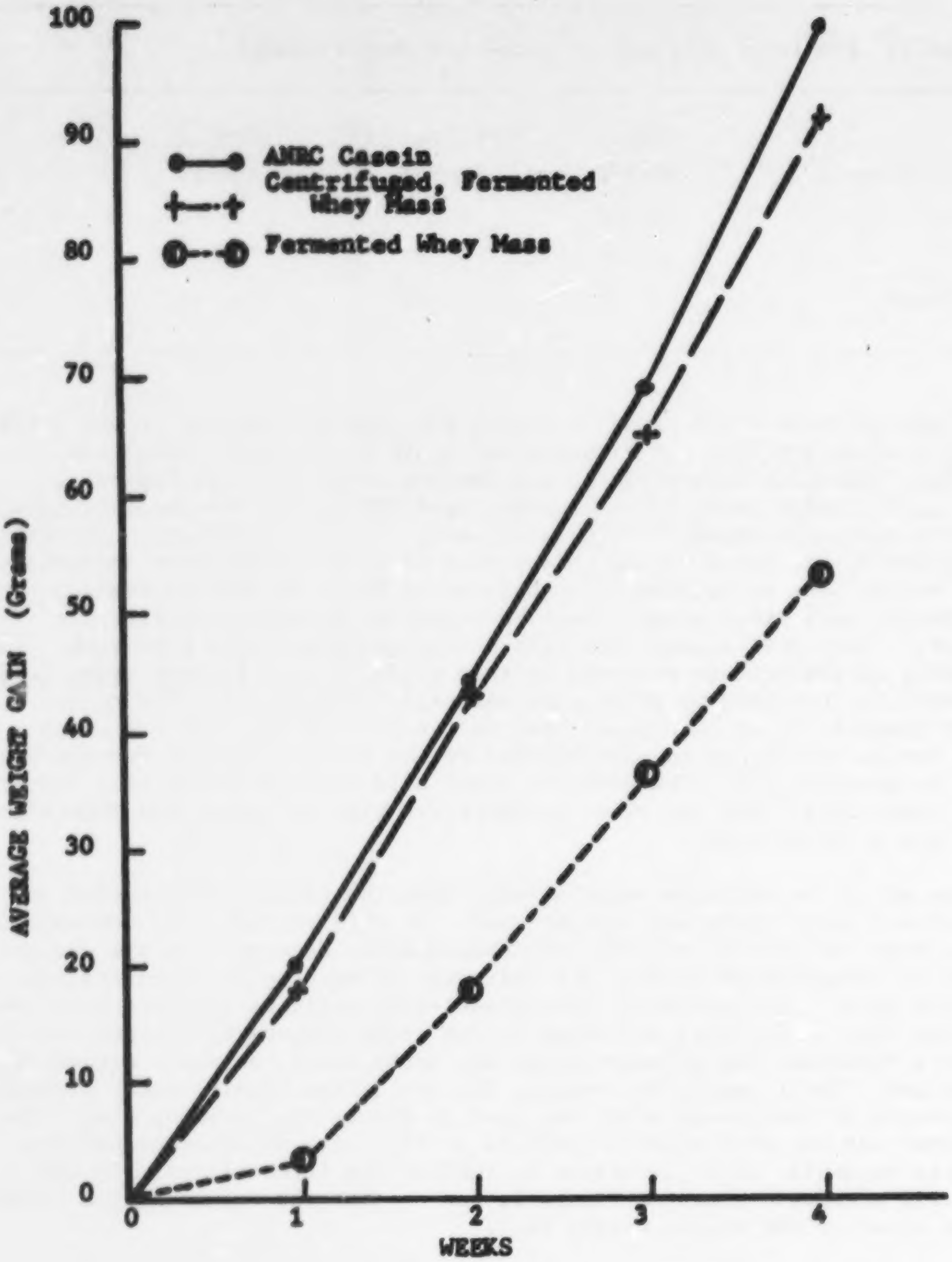
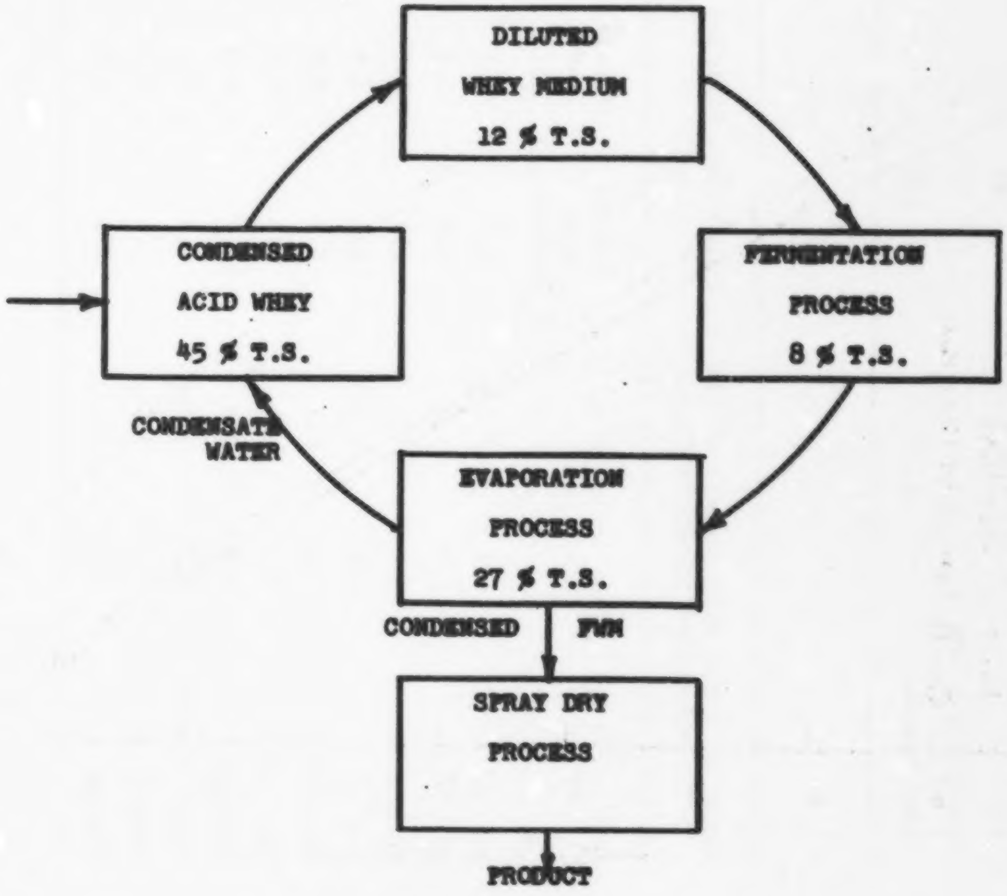


FIGURE 6

CLOSED-LOOP SYSTEM FOR MINIMIZING EFFLUENTS


CONDENSED
ACID WHEY
45 % T.S.
DILUTED
WHEY MEDIUM
12 % T.S.
FERMENTATION
PROCESS
8 % T.S.
EVAPORATION
PROCESS
27 % T.S.
CONDENSATE WATER
CONDENSED FWM
SPRAY DRY
PROCESS
PRODUCT

If higher grades of the product are desired, additional processing through centrifuges are necessary. This would entail a supernatant effluent that would have to be disposed of and processed further by some form of waste treatment. However, it was found that the yeast slurries could be handled through the centrifuges after partial evaporation which reduces the volume substantially.

Table 2. Protein Efficiency Ratio (PER) Assays

	Ave. PER Value 4 weeks	% of ANRC Casein
FWM	1.72	69
Centrifuged FWM	2.26	91
ANRC Casein	2.50	100

Table 3. Amino Acid Content of Various Single Cell Proteins Compared to FAO Profile

Amino Acid	FAO Profile	*S. fragilis* Yeast	Brewers Yeast	Torula Yeast	Esso Yeast
	% of Total Protein				
Lysine	4.2	6.9	6.8	8.5	6.5
Threonine	2.8	5.8	5.9	5.1	4.0
Methionine	2.2	1.9	1.5	1.5	2.0
Valine	4.2	5.4	4.7	5.6	4.5
Leucine	4.8	6.1	5.8	8.0	5.6
Isoleucine	4.2	4.0	3.6	6.4	3.6
Tyrosine	2.8	2.4	2.7	4.3	---
Phenylalanine	2.8	2.8	3.4	5.1	2.9
Tryptophan	1.4	1.0	1.1	---	---
Histidine	---	2.1	2.1	2.2	---

ECONOMICS

From the experimental results in the 500 gallon fermentor, it is possible to calculate the approximate cost of the product in a full scale plant. It was found that in a continuous fermentation, the actual yield is 0.9 to 1.0 pounds of solids in the whole fermented whey mass (FWM) per pound of lactose in the original whey. Since the lactose content of the whey solids is about 70%, one would therefore realize about two-thirds of a pound of FWM solids from each pound of whey solids in the original medium. Using a 20,000 gallon fermentor, operated continuously, as in the pilot plant, and using a 300 day production year, 3600-4000 tons of dried FWM could be produced annually.

The cost of the medium for the fermentation is based on a 10-12% solids level and will be primarily determined by the price of whey. While it is not difficult to foresee a time when this material will have a negative value due to the necessary cost of waste treatment and pollution abatement, at the present time it may be possible to obtain the needed whey for no cost or for the cost of evaporation or transportation alone. Using a cost of whey of zero as a low value and 2¢ per pound solids as a high value, medium costs will be in the range of 2.5-5.7¢ per pound of product.

The cost of production is affected by the size of the operation. The cost of labor and operations decrease on a per pound, finished product basis as the size of the equipment and its degree of sophistication increases. However, as the capacity increases so does the capital investment with its connected charges for depreciation, taxes, insurance and physical facilities.

A plant capable of an annual production of 4,000 to 10,000 tons per year would cost from 5 to 15 million dollars depending on the design and this is still considered a small fermentation plant. Those being designed for the production of single cell protein (SCP) from hydrocarbons are in the 100,000 ton annual capacity range (10).

The operating costs of a yeast-whey fermentation, including those for utilities, power, aeration, recovery and processing are lower than other processes for producing similar materials from other substrates. The aeration requirement for the fermentation of hydrocarbons is 2.5 to 5.0 times that of the fermentation of a carbohydrate such as lactose (11). Because of the solubility of the whey substrate, agitation and power needs are lower as is the amount of cooling. All these costs plus other factors are included in Table 4. They show calculated production cost estimates for FWM and those of SCP material produced on hydrocarbons (11) and on cellulostic wastes (12). The basis of the production capacities are 100,000 tons per year for the products from hydrocarbons or cellulose raw material and 4000-8000 tons per year for FWM from whey.

Table 4. Production Cost Estimates of Single Cell Proteins

Raw Material	Acid Whey	Hydrocarbon (11)	Cellulose (12)
Annual Capacity in tons product	4000-8000	100,000	100,000
Costs: Cents per pound of product			
Medium	2.5-5.7	2.0-4.0	3.0
Operating and Utilities	2.8	3.1-4.5	1.5
Labor	1.9	0.6	0.6
Capital Investment	2.0-3.0	1.2-2.1	1.6
Total Cost	9.2-13.4	6.9-11.2	6.7

SUMMARY

The experimental data and experience obtained operating this demonstration pilot plant over an extended period of time allows the following conclusions.

Saccharomyces fragilis may be grown on an acid (or sweet) whey medium in a deep tank, aerated, agitated fermentor in a continuous manner. While similar fermentations have been described and demonstrated in the literature, this study has shown that variations in fermentation conditions, strain selection, and medium composition produced cell counts of several billion cells per milliliter that may be maintained for extended periods of time.

The fermentation itself has many advantages easily recognized by the experienced investigator. By operating at a low pH (4.5) and with a large seed size and high cell count, contamination is no problem and therefore, sterile or special aseptic equipment or techniques are not necessary. The aeration requirements are not excessive with adequate agitation and efficient baffling, nor is this any problem in foam control. Temperature control, despite the rapid growth rate was maintained with a low level of cooling water. The medium is simple in composition, and, at the concentrations used, the carbohydrate (lactose) is completely soluble. The absence of potential toxic substances in the medium simplifies harvesting. The production of a dried whole fermented mass precludes additional processing of waste streams from yeast separators and increase the yield of the fermentation. As a result of the evaporation of the whole fermented mass prior to drying, condensate water is obtained that can be used to dilute incoming condensed whey and thereby operate a completely closed-loop system with no effluents.

If a higher protein, food grade yeast is desired, the cells may be harvested from the medium by centrifugation. The yeast cells are sufficiently large for efficient centrifugation by standard yeast separators.

The protein quality of the finished products is good, although slightly low in the sulfur containing amino acids, as is true of most single cell proteins. While rat feeding tests show no toxicity, feeding experiments with other animals must be run to confirm nutritional quality and appropriate feed ration levels.

The cost of production is dependent primarily on two factors - the cost of whey and the capital investment. Efficiency demands a plant that is highly automated and instrument controlled and of a size to have an annual capacity of at least 4000-10,000 tons of finished product. This would represent a raw material requirement of the equivalent of 200 to 500 million pounds of raw whey. Therefore the location of such a facility must be near a large cheese producing area. Such an area will have excess whey available at little or no cost. The capital investment is large, but must be made to allow the product to compete in the market place.

The present and future shortage of protein has been reported in both the scientific and lay press. Statements such as "The United Nations has already officially labeled the protein shortage a crisis" and "The protein crisis is just as real as the energy crisis and perhaps more immediate" (13) have brought this to the attention of many persons. The shortage of high quality protein for animal feeds is one of the major reasons for the present high price of meat. Soy bean meal, which contains 40% protein and is the major source of protein in animal feeds, is selling for more than two times that of a year ago. Many investigators are examining various waste products - such as manure, waste paper, used tires - as a substrate source on which to produce single cell protein. Whey is a clean wholesome substance, in excess supply and a potential environmental pollutant. By the fermentation described here, this can be converted into a useful and needed high-protein material, the demand for which is now present and should increase in the future.

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Impact of the Individual Quick Blanch (IQB) Process on Cannery Waste Generation**

by

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In the conversion of raw product to shelf-stable canned product, waste streams of significant volume and strength are generated. Surveys of the individual unit operations in this process indicate that blanching contributes significantly to overall plant effluent (1), (2). Consequently, recent investigations have been undertaken to design a blanching operation which would significantly reduce the generation of waste water. One such investigation led to the development of the individual quick blanch (IQB) process (3). IQB is a two-stage process: 1) each piece of product is exposed to a heat source for such duration that the mass-average temperature is in the range desired, and 2) the piece is held adiabatically until the temperature has equilibrated to the mass-average and the objectives of blanching have been accomplished.

Lund (4) reported on the application of IQB to vegetables prior to canning. In that study, peas, corn, lima beans and green beans were blanched by: 1) the IQB process, 2) the IQB process with predrying, and 3) pipe blanching. Compared to pipe blanching, the IQB process reduced waste water generation by up to 99%. The study also revealed that although predrying to greater than a 6% weight reduction would further reduce waste water generation, product quality was adversely affected.

The present study was undertaken for several reasons: 1) to confirm the 1971 results with IQB, 2) to compare the IQB process to deep-bed steam blanching, 3) to apply the IQB process to different varieties of peas, 4) to extend the IQB process to the blanching of root vegetables such as carrots, beets and potatoes, and 5) to compare the IQB process to the short-duration heat-only stage of the IQB process.

Methods

Five different blanching methods were compared in this study: 1) IQB with the product predried to approximately a 6% weight reduction, 2) IQB without predrying, 3) the heat only stage of the IQB process (no hold section), 4) deep bed steam blanching, and 5) pipe blanching. For predrying, vegetables obtained from a local canning plant were cycled through a six-foot vibrating

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** This investigation was supported by the College of Agricultural and Life Sciences, University of Wisconsin-Madison, the Environmental Protection Agency, under project No. S801484, the Wisconsin Canners and Freezers Association and the Wisconsin State Department of Natural Resources.

bed dryer with air at 160-180°F (dry bulb) until approximately 6% weight reduction was achieved. The IQB unit described by Lazar et al. (3) and Lund (4) was used for all steam blanching experiments and runs were carried out in our laboratory. Pipe-blanched product was obtained directly from the canning plant after it was canned and thermally processed.

For each experimental run, three twenty-pound batches of the vegetable were treated by one of the four steam blanching methods. Initial weight, weight after drying (if the product was predried), and weight after blanching were recorded. For each twenty-pound run, all waste water generated by processing the vegetable in the blancher was measured. A composite sample of the waste water was subjected to analysis for the following: 1) BOD_5, 2) COD, 3) total solids, 4) suspended solids, 5) soluble phosphorus, 6) total phosphorus, 7) total organic nitrogen, 8) NH_3-Nitrogen, 9) NO_3-Nitrogen, 10) NO_2-Nitrogen, and 11) pH. Part of the analyses were performed by the Wisconsin Department of Natural Resources. In all cases the standard methods for analyses were used (5).

In order to report waste water generation on the basis of amount of product processed, a blank was determined for each run by operating the equipment with the steam on and the belts moving for a period of time equal to the time to process the twenty-pound lot. Equipment effluent (due to heat losses from the equipment and heating the belt and any water carried in the steam line) was measured and this value subtracted from the volume generated during the actual run. All analysis values were corrected by the resulting dilution factor. Immediately following blanching, samples were filled into 303 cans to the appropriate fill weight, brine added, cans sealed and retorted in a Steritort following the heat/cool process used in the canning plant.

For the pipe blancher, effluent was collected at the dewatering reel and subjected to the same analyses as other samples. Water usage was monitored by a water meter in the water make-up line and was recorded daily. By knowing the daily case pack on the line, the gallons of water per case of product could be calculated. Since the pipe blanching water was heated by direct steam injection, the effluent generated by the system was larger than that calculated from the water make-up readings. To adjust for the steam condensation in heating the product up, it was assumed that 9.3 pounds of steam would condense for every 100 pounds of product being heated 100°F. This resulted in 22 gallons of steam condensation per ton of product. This value has been added to all pipe blancher values as calculated from water meter readings. Waste generation reported for the pipe blanching system will still be low since this does not account for heat losses from the piping system. However, for the system we monitored heat losses would probably not contribute more than 2-5 gal/ton of product processed.

To insure that representative samples of waste water were being collected from the pipe blancher, on some occasions (at least two days for each vegetable), water samples were collected at two-hour intervals. Results indicated that within two hours of start-up the blancher water was in steady state. Therefore, all samples were taken at least two hours after start-up. For later evaluation and comparison, several cases of canned vegetables processed at the same time the experimental samples were processed were brought to the laboratory.

Blanching times used in the IQB heat/hold sections were determined by making simple observations on the pipe blanching operation. For peas, it was observed that conventional pipe blanching operation resulted in peroxidase inactivation and, therefore, peroxidase inactivation was the criterion for establishing heat/hold times in IQB. For corn and lima beans, water temperature in pipe blanching was approximately 170°F and, consequently, heat/hold times were chosen that would result in a final corn or lima bean temperature of 170°F. Green beans were also pipe blanched at 170°F but the conventional IQB process could not be used. With green beans, the function of blanching is to activate the enzyme pectin methyl esterase which prevents sloughing of the green bean following canning. Since the enzyme is inactivated at temperatures above 180°F, the IQB heat section could not be heated with 212°F steam. Therefore, a steam-air mixture at 175°F was used in the IQB heating section. Heat/hold times were chosen that would result in an equilibrated temperature of 170°F. For potatoes, carrots and beets, a direct comparison to pipe blanching could not be made since these products are not usually blanched prior to canning. The only heat treatment these products receive prior to retorting is in the peeling operation. These products were included in the IQB and deep-bed experiments, however, since they are blanched prior to freezing and some processors have experienced undesirable color changes (particularly with beets and potatoes) which can be avoided by blanching after slicing or dicing. For deep-bed blanching, all vegetables were blanched for 2.5 minutes, the maximum residence time of the IQB heat section. The bed depth was 2-2.5 inches resulting in belt loadings ranging from 2.5 to 3.5 lb/ft^2. For the IQB heat section belt loadings were 1.1 $\pm$0.3lb/ft^2 and for the hold section, belt loading range was 4-17 lb/ft^2. Blanching conditions for all vegetables are given in Table 1.

Subjective evaluation of the blanched-canned vegetable was carried out at one, three, six and nine months' storage by taste panel triangle-difference-test between conventionally processed product and experimentally blanched-canned product. Objective evaluations were also made at that time. Objective evaluation included drained weight, can vacuum, brine sediment (applicable only to peas), percent splits (applicable only to green beans and peas) and percent slough (applicable only to green beans (6)).

Products tested were: peas--number 3 and 4 sieve Alsweet, Alaskan or Perfection variety; corn--Midway Whole Kernel; lima beans--Thorogreen, 3 sieve; green beans--Slim Green, 1.5 in. cut; potatoes--Superior, 1/4 in. slice, medium; carrots--Nantes, 1/4 in. slice, medium; and beets--Ruby Queen, 1/4 in. slice, medium.

Results and Discussion

Tests conducted with the smooth-skinned variety of pea (Alaskan) and the wrinkled-skinned variety (Alsweet and Perfection) indicated that there was no significant difference in either the quantity or quality of the waste generated in blanching. Also, there did not appear to be any significant effect of harvest date on effluent characteristics. Consequently, data reported for peas are average values of all runs for that experimental condition. Tables 2 and 3 present characteristics of the waste generated from pea blanching and the losses during blanching. Although a large number of waste characteristics were determined, for brevity only some selected values are presented here (BOD/total org. N/total phosphorus). A complete presentation of data will be made available through the final report on this project to EPA.

Table 1

Blanching Times and Temperatures[a]

Commodity	IQB	Heat Only	Deep Bed	Pipe
Peas	30 sec/212 Heat 45 sec Hold	30 sec/212	2.5 min/212	4 min/200
Corn	20 sec/212 Heat 30 sec Hold	20 sec/212	2.5 min/212	1.5 min/170
Lima Beans	20 sec/212 Heat 80 sec Hold	20 sec/212	2.5 min/212	4 min/170
Green Beans	20 sec/180 Heat 80 sec Hold	--	2.5 min/180	2 min/170
Potatoes	60 sec/212 Heat 60 sec Hold		2.5 min/212	
Carrots	45 sec/212 Heat 60 sec Hold		2.5 min/212	
Beets	45 sec/212 Heat 60 sec Hold		2.5 min/212	

[a] All time/temperature combinations resulted in negative peroxidase except green beans. Time/Temperature (°F)

Table 2

Pea Blanching

Blanching Method	Gal/[A] Ton	BOD_5[B] (lb/ton)	Total[C] Org N_2 (lb/ton)	Total[D] Phos. (lb/ton)
IQB-6.9	32	3.1	0.16	0.04
IQB	47	4.5	0.23	0.06
30 Sec.	46	4.5	0.23	0.06
Deep Bed	63	7.1	0.37	0.08
Pipe	92	6.0	0.34	0.09

[A] ± 5 gal/ton product

[B] ± 1 lb/ton product

[C] ± 0.05 lb/ton product

[D] ± 0.01 lb/ton product

Table 2 presents the characteristics of the waste generated in each of the four steam blanching methods and the pipe blanching method. The coding on "Blanching Method" is: (1) IQB-6.9 - IQB blanching process with a 6.9% weight reduction prior to steaming, (2) IQB - IQB blanching process, (3) 30 sec - heat only section of IQB process, (4) deep bed - deep-bed steam blanching, and (5) pipe - commercial pipe blanching. Compared to pipe blanching, all of the steam blanching methods resulted in reduced effluent generation. Predrying reduced waste generation by 68% while deep bed reduced the gal/ton product processed by 32%. As expected IQB and 30 sec. blanching treatments were equivalent in waste generation indicating that all of the waste was generated in the heating section of the blanching unit and little or no losses occurred in the hold section. Deep bed blanching effluent was greater than that for IQB. This is probably because in deep bed steam blanching the mass average temperature was higher than in IQB due to the increased residence time (2.5 minutes compared to 30 seconds). This resulted in less water adhering to the surface of the peas and loss of juice from overcooked peas. Table 3 presents losses in the blanching operation. Losses with deep bed blanching are greater than with IQB blanching. Total loss represents total weight loss in the process; whereas product loss represents loss of solids in the effluent, expressed in weight of product. Interestingly, the BOD/N/P ratio was rather constant for all blanching methods with an average of 77/4/1.

Results from corn blanching studies are given in Tables 4 and 5. As with peas, waste generated and its characteristics were independent of harvest time. All corn was mature and therefore the effect of maturity on effluent characteristics was not determined. The data parallel that of peas for the gallons of waste generated per ton of product for the various blanching methods. However, for a given method of steam blanching the gal/ton was lower for corn blanching than for pea blanching. This can be attributed to the greater water holding capacity of the corn surface compared to the pea and the presence of starch on cut surfaces of corn. In pipe blanching, water usage for corn was nearly double that for peas. This reflects the fact that with corn blanching the process is basically a wash step to remove reducing sugars and other components that contribute to brown color development during thermal processing. This was shown in our taste panel evaluation of steam blanched samples compared to pipe blanched samples when the only significant difference between the products was color. To maintain a bright golden, yellow color corn would have to be thoroughly washed prior to steam blanching which introduces another dilute waste stream into the total plant effluent. The advantage of producing bright yellow corn must be weighed against the disadvantage of creating large volume-low solids effluent streams.

The BOD/N/P ratio for corn effluent averaged 93/0.94/1 considerably different from the suggested 100/5/1 for biological waste treatment. Values for BOD_5, nitrogen and phosphorous were in direct proportion to the effluent volume indicating that leaching is a significant factor in generation of waste streams even in steam blanching. BOD/COD ratio for corn was 0.60.

IQB with predrying produced only 11% of the effluent produced by pipe blanching while IQB produced 17%. Effluent generation, however, is not the only characteristic that selection of a suitable blanching process can be based on. Examination of Table 5 reveals that with the predrying-IQB process total

Table 3

Losses in Pea Blanching

Blanching Method	Total Loss^A (%)	Product Loss^B (%)
IQB-6.9	11.3	1.5
IQB	10.7	2.0
30 Sec.	9.6	2.1
Deep Bed	16.7	3.1
Pipe	--	2.5

[A] ± 0.5% (w/w)

[B] ± 0.2% (w/w) Calculated from solids in effluent by assuming peas are 20% solids.

Table 4

Corn Blanching

Blanching Method	Gal/ton^A	BOD_5 (lb/ton)^B	Total Org N_2 (lb/ton)^C	Total Phos (lb/ton)^D
IQB-7.5	19.5	2.7	0.016	0.033
IQB	29.7	5.2	0.038	0.076
IQB-20	28.9	5.8	0.036	0.071
Deep Bed	36.7	8.3	0.052	0.092
Pipe	175	10.0	0.182	0.069

[A] ± 5 gal/ton product

[B] ± 1 lb/ton product

[C] ± 0.005 lb/ton product

[D] ± 0.005 lb/ton product

Table 5

Losses in Corn Blanching

Blanching Method	Total Loss[A] (%)	Product Loss[B] (%)
IQB-7.5	6.9	0.44
IQB	2.9	1.6
20 Sec.	2.7	1.5
Deep Bed	5.8	2.4
Pipe	--	2.9

[A] ± 0.5% (w/w)

[B] ± 0.2% (w/w) Calculated from solids in effluent by assuming corn is 25% total solids.

Table 6

Lima Bean Blanching

Blanching Method	Gal/Ton[A]	BOD_5[B] (lb/ton)	Total[C] Org N_2 (lb/ton)	Total[D] Phos. (lb/ton)
IQB-5.0	15.4	0.7	0.04	0.007
IQB	38.5	5.0	0.32	0.06
20 Sec.	30.6	8.1	0.15	0.04
Deep Bed	49.8	8.5	0.46	0.12
Pipe	197	1.1	0.051	0.01

[A] ± 5 gal/ton product

[B] ± 1 lb/ton product

[C] ± 0.05 lb/ton product

[D] ± 0.02 lb/ton product

loss was greater (total yield was less) than with the IQB process (6.9% total loss compared to 2.9% total loss, respectively). Predried corn did not fully rehydrate during the steaming process in the blancher and, therefore, yield was less. This incomplete rehydration of product following predrying was reported last year (4) and the product loss must be weighed against the cost of waste stream treatment to determine the most economical blanching process.

Results with lima beans are presented in Tables 6 and 7 and parallel those of peas and corn in terms of effluent generation for each method. The only noted exception is the lower effluent generation in the heat-only process compared to IQB. The 30.6 gal/ton compared to 38.5 gal/ton shows that with lima beans there is considerable waste generation in the hold section. From product loss figures in Table 7,cell destruction in lima beans during steaming results in additional juice loss upon holding. Effluent characteristics are like those of peas, giving a BOD/N/P ratio of 93/5/1 and a BOD/COD ratio of 0.59.

Tables 8 and 9 present results with green beans, potatoes, carrots and beets. For these products, IQB and deep bed blanching result in nearly the same effluent quantity because the mass average temperature for both processes is about the same. Residence times for potato, carrot and beet slices in the IQB heating section were long enough to achieve higher mass average temperatures than with peas, corn, lima beans or green beans. Average BOD/N/P ratios for the four products were: green beans - 130/3.4/1; potatoes - 53/3.7/1; carrots - 184/19/1; and beets - 195/3.8/1. BOD/COD ratios were: green beans - 0.60; potatoes - 0.64; carrots - 0.71; and beets - 0.66.

In the evaluation of any alternative blanching method product quality is of primary consideration. In all of the objective and subjective tests performed in this study, in only three cases did commercially canned product prove superior to experimentally-blanched, canned product. Corn, potatoes and carrots had better color in commercial samples, with experimentally blanched samples all being darker. With corn, as discussed earlier, this was due to the thorough washing that pipe-blanched samples receive during blanching. With potatoes and carrots, steam blanched products were darker due to process delay in transporting product from the plant to the laboratory.

One last consideration can be made and that is the size of an industrial IQB blancher. By knowing residence time and belt loading in the IQB process, blancher size can be determined. For blanching times given in Table 1 the capacity of an IQB unit with a 5 ft x 30 ft heat belt and a 5 ft x 4.5 ft hold belt is given in Table 10.

Conclusions

1. The IQB process resulted in a significant reduction in waste generation as compared to pipe blanching.
2. With all products tested except corn, the IQB-blanched canned product was as acceptable as the pipe-blanched canned product. With corn, color was darker on all steam blanched product.

Table 7

Losses in Lima Bean Blanching

Blanching Method	Total Loss[A] (%)	Product Loss[B] (%)
IQB-5.0	2.5	0.24
IQB	8.8	1.1
20 Sec.	4.1	0.75
Deep Bed	16.6	1.9
Pipe	--	0.25

[A] ± 0.05% (w/w)

[B] ± 0.2% (w/w) Calculated from solids in effluent by assuming lima beans are 32.5% solids.

Table 8

Characteristics of Effluents from Blanching

Product	Blanching Method	Gal/Ton[A]	BOD_5[B] (lb/ton)	Total Org N_2[C] (lb/ton)	Total Phos[D] (lb/ton)
Green Beans	IQB	32.4	1.9	0.06	0.016
	Deep Bed	23.8	1.1	0.03	0.009
	Pipe	70.0	--	--	--
Potatoes	IQB-6.9	22.6	0.9	0.06	0.017
	IQB	38.5	1.4	0.09	0.022
	Deep Bed	37.7	1.2	0.13	0.032
Carrots	IQB	42.5	3.7	0.19	0.030
	Deep Bed	50.5	4.9	0.26	0.042
Beets	IQB-5.6	41.0	10.0	0.19	0.050
	IQB	49.6	8.9	0.15	0.039
	Deep Bed	48.2	8.6	0.20	0.055

[A] ± 5 BOD/ton product

[B] ± 1 lb/ton product for carrots and beets; ± .1 lb/ton product for green beans and potatoes.

[C] ± 0.01 lb/ton product for green beans, potatoes, and beets; ± 0.05 lb/ton product for carrots.

[D] ± 0.002 lb/ton product for potatoes; ± 0.001 for green beans; ± 0.005 for carrots and beets.

Table 9

Losses in Blanching

Product	Blanching Method	Total Loss[A] (%)	Product Loss[B] (%)
	IQB	4.0	1.4
Green Beans	Deep Bed	1.0	0.7
	IQB-6.9	6.9	0.43
Potatoes	IQB	6.6	0.61
	Deep Bed	6.3	0.78
Carrots	IQB	8.2	1.9
	Deep Bed	11.6	2.8
	IQB-5.6	13.8	5.2
Beets	IQB	11.1	4.0
	Deep Bed	10.6	5.3

[A] ± 0.05% (w/w)

[B] ± 0.2% (w/w) Calculated from solids in effluent by assuming green beans are 10% solids; potatoes, 20.2%; carrots, 11.8%; and beets, 12.7%.

Table 10

IQB Unit[A]

Product	Production Rate (tons product/hr)
Peas	10
Corn	15
Lima Beans	15
Green Beans	15
Potatoes	5
Carrots	6.3
Beets	6.3

[A] Heat 5 ft. wide x 30 ft. long loaded at 1 lb/ft^2.

Hold 5 ft. wide x 4.5 ft. long loaded at 10 lb/ft^2.

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IN-PLANT HOT-GAS BLANCHING OF VEGETABLES[***]

by

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INTRODUCTION

The food processing industry is now evaluating the economic consequences of radical changes in processing equipment as one option available to meet the national goal of zero discharge of pollutants by 1985. It is likely that new technology for raw product preparation which substantially reduce waste generation will be less costly than expansion of treatment facilities.

It has long been known that the preliminary heat treatment (blanching) which most vegetables and a few fruits receive before preservation by freezing, canning, or dehydration is a source of strong liquid wastes. For example, the blanching and peeling of beets, carrots, and potatoes account for 85, 65, and 89 percent respectively of the total BOD generated in the processing of these commodities (1). It has been estimated (2) that the national amortized annual treatment facility cost for liquid wastes from selected vegetable blanching is 2.4 million dollars and the annual maintenance and operating cost is 3 million dollars. The study of low water volume methods of vegetable blanching has every promise of developing new technology with the desirable features of reducing treatment plant loadings and/or facilitating closed loop use of water.

A preliminary study of two potential low water volume methods of blanching was accomplished under U. S. Environmental Protection Agency Grant 12060 PAV (3). A comparison of the results of blanching seven vegetables with microwave, hot-gas, steam, and hot-water blancher simulators revealed exceptional promise for the new method of hot gas blanching. There were no major significant differences found in product quality, vitamin and mineral retention or internal can corrosion when samples of vegetables prepared with the four different blanching systems were compared. An estimate for commercial blanching using the four systems studied led to the following cost factors per ton of raw vegetable blanched: microwave $18.47, hot-gas $3.39, steam $2.21, and hot-water $2.36.

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[***] This investigation was supported by funds from the U. S. Environmental Protection Agency, Office of Research and Monitoring, under Grant S 800250 and the National Canners Association

The initial study of hot-gas blanching done in a pilot plant had several limitations. The most serious limitation was the requirement of long transport distances and time delays for prepared raw vegetables before blanching. These delays before blanching were especially serious for green peas, green beans and asparagus. The use of prepared raw vegetables which were not typical of commercial processing made the significance of some data uncertain. The pilot plant work was limited to short duration blanching runs due to raw product costs. Also, in long duration blanching runs it would have been necessary to waste large quantities of wholesome food. A third limitation of the pilot plant work was the lack of measurement of power, gas and steam usage for more precise cost estimates. The pilot plant work, despite the limitations, did demonstrate the exceptional promise of hot-gas blanching as a low water volume blanching method. The next stage in the determination of the commercial utility of hot-gas blanching was in-plant work using commercially prepared raw vegetables as feed to a metered installation with return of blanched material to production.

EXPERIMENTAL

The hot-gas blancher used in the in-plant studies was the experimental unit described previously (3). The blancher was installed using electrical meters for the large blower, the combustion air supply turbine, the conveyor drive and the gas furnace ignitor and electronic controls. A gas meter was placed on the inlet side of the natural gas furnace. A Fisher and Porter Model 10A1152-55EM steam flow meter rated at 21 lb/min at 100 percent of scale was installed on the steam inlet line. A FMC Syntron Model No. BF-2 electric vibratory feeder was used to control the rate of feeding of green beans and beets onto the conveyor belt of the hot-gas blancher. Dry belt conveyors were used as much as possible to accomplish the transfer to both raw and blanched vegetables. Raw No. 4 sieve size cut green beans were delivered to the hot-gas blancher in 800 lb capacity tote boxes using fork lift trucks. Spinach was transported to a feed conveyor in a 500 lb capacity wheeled cart. Corn-on-cob and beets were carried in 30 lb capacity plastic pails.

The long duration runs were preceded by a number of short duration runs used to work out operating conditions which produced blanched material yielding final product satisfactory to plant quality control specifications.

During the long duration runs, the meters, conveyor speed control setting, and the temperature indicator were read and recorded at frequent intervals. The feed and product weight of material going through the hot-gas blancher was determined by weighing or by a combination of piece count and weighing. A total flow wastewater sample was collected for each 8 hr of operation of the hot-gas blancher. A sample of hot-gas blanched material was collected each hour and measured for peroxidase content (4). Samples of raw, hot-gas blanched, hot-water or steam blanched (commercial) vegetable were frozen for later determination of vitamin and mineral content (5). Canned or frozen samples were obtained for organoleptic panel evaluation of quality.

RESULTS

Spinach Blanching

A partial study of hot-gas blanching of spinach was made in March, 1972; a more detailed study is scheduled during the 1973 canning season.

The results of short duration runs with washed spinach are tabulated in Appendix A. These runs were sufficient to prepare enough samples for quality evaluations and to receive approval of the cannery management to make long duration runs and return hot-gas blanched spinach to commercial production.

The results of the long duration hot-gas blanching of spinach are tabulated in Table 1. The residence time of the spinach in the heated section of the hot-gas blancher was 108 sec. During 19.4 hours of operation of total of 6800 pounds of washed spinach was blanched; the total weight of blanched material was 5700 pounds.

The hot-gas blancher wastewater characteristics are tabulated in Table 2 and the commercial steam and hot-water blancher wastewater characteristics in Table 3.

For comparative purposes, the volume of wastewater discharged from the commercial blanchers for each commodity studied was measured and a grab sample collected every 2 hours. The grab samples and a composite sample from each 8 hours of operation of the commercial blancher were analyzed for pH, COD, BOD, and suspended solids (6) as were the 8 hour (total effluent) wastewater samples from the hot-gas blancher. Headspace gas analysis of canned samples were made as a measure of removal of oxygen from the tissue of blanched vegetables.

TABLE 1

Long Term Hot-Gas Blanching of Washed Spinach

Hrs of Operation	Feed Wt, lb/hr	Temp. °F	Peroxidase Reduction, %	Wastewater Volume, gal
1	-	230	97	.125
2	-	245	97	.063
3	445	220	-	.064
4	-	240	99	.063
5	-	225	-	.060
6	-	230	99	.061
7	-	240	99	0.007
8	265	235	-	0.039
9	-	230	99	0.004
10	340	220	-	0.001
11	-	210	99	0.125
12	250	220	-	0.009
13	-	220	99	0.003
14	340	230	-	0.007
15	-	220	-	0.033
16	380	230	-	-
17	-	220	-	0.014
18	340	220	-	-
19	-	210	99	0.022

TABLE 2

Hot-Gas Spinach Blanching, Wastewater Characteristics

Date/Time	Volume, gal	Tons Blanched	COD, mg/l	SS, mg/l	pH
3/27					
12:40	0.125		30,500	5,900	7.6
1:40	0.063		31,800	2,090	7.7
2:40	0.064		52,400	7,920	7.4
3:35	0.063		69,000	6,340	7.6
4:35	0.060		68,500	5,590	7.4
5:10	0.061		67,000	8,870	7.2
Total	0.435	1.31	49,900*	3,430*	
3/28					
11:00	0.007		194,200	12,340	7.7
12:50	0.039		201,000	4,360	7.6
1:35	0.004		146,900	5,860	7.9
2:35	0.001		275,800	10,440	7.6
3:35	0.125		104,000	1,430	7.6
Total	0.176	0.86	131,520*	2,590*	
3/29					
8:30	0.009		6,200	360	7.4
9:30	0.003		3,300	810	7.4
10:30	0.007		179,500	10,620	7.6
12:00	0.009		26,900	1,700	7.4
1:00	0.033		226,900	6,230	7.6
2:00	0.014		42,400	2,530	7.7
3:00	0.022		259,500	6,670	7.5
Total	0.097	1.72	156,880*	3,520*	

* - Volume Weighted Average

TABLE 3

Commercial Spinach Blanching Wastewater Characteristics

Date	Time	Ton Blanched	COD, mg/l	SS. mg/l	pH
3/27 - Hot Water Overflow					
	12:40		260	50	7.8
	1:40		160	70	7.7
	2:40		270	50	7.7
	3:35		230	40	7.7
	4:35	29.2	240	30	7.7
	Average		230	48	
3/28					
	8:00		510	70	7.5
	9:30		300	70	7.6
	10:00		480	170	7.6
	12:50		330	140	7.6
	2:40		250	90	7.7
	3:00	59.5	300	90	7.7
	Average		360	105	
3/29					
	8:30		270	60	7.0
	9:30		290	70	6.9
	12:00		340	130	6.9
	1:00		270	60	6.9
	2:00		430	170	6.8
	3:00	52.0	340	100	6.8
	Average		320	98	
3/27 - Steam Condensate Overflow					
	12:40		4040	140	7.0
	1:40		4120	120	7.0
	2:40		4370	120	7.0
	3:35		4330	130	7.0
	4:35	29.2	4450	80	7.0
	Average		4260	118	

TABLE 3 (Cont'd)

Commercial Spinach Blanching Wastewater Characteristics

Date	Time	Ton Blanched	COD, mg/l	SS, mg/l	pH
3/28					
	8:00		4120	110	7.1
	9:30		4080	70	7.0
	10:00		4080	120	7.1
	12:50		3880	100	7.1
	2:10		3960	60	7.7
	3:00	59.5	3960	80	7.7
	Average		4010	90	
3/29					
	8:30		4410	140	7.1
	9:30		4690	110	7.1
	12:00		3550	140	7.1
	1:00		4450	140	7.1
	2:00		4120	120	7.1
	3:00	52.0	4330	160	7.1
	Average		4260	135	

The wastewater discharged from the commercial blancher was measured at two points: 1) steam condensate overflow which had a volume of 1800 gph and 2) hot-water makeup overflow which had a volume of 3600 gph.

The installation of the hot-gas blancher for spinach did not have electrical meters; the natural gas use was 3,100 cu. ft. for the 19.4 hours of operation.

The headspace gas analytical results are tabulated in Table 4.

TABLE 4

Headspace Gas Analysis of Canned Spinach

Blanching Unit	Headspace Volume, ml	N_2	CO_2	Argon + O_2	H_2
Hot-Gas	146.4	87.6	10.7	1.7	0
Commercial (Hot Water)	39.6	88.5	4.3	5.3	1.9

The results of analysis of canned samples of spinach for their content of carotene, riboflavin (Vitamin B_2) and ascorbic acid (Vitamin C) are tabulated in Table 5.

The content of calcium, magnesium, phosphorus and iron in samples of canned spinach are tabulated in Table 6.

TABLE 5

Vitamin Content of Canned Spinach Samples*

Blanching Treatment	Carotene	Vitamin B_1	Vitamin C
Commercial			
Can 1			19.2, 16.9
Can 1A	5.4	0.115	
Can 2			18.5, 20.8
Can 2A	5.3	0.123	
Can 3			28.7, 28.7
Can 4			22.2, 21.5
Can 5			11.6, 13.0
Can 6			22.7, 25.5
Average	5.4	0.119	20.8
Standard Deviation	---	---	5.6
Hot-Gas			
Can 1			43.1, 42.6
Can 1C	3.1	0.105	
Can 2			32.9, 32.2
Can 2D	4.0	0.103	
Can 3			25.9, 23.2
Can 3E	3.4		
Can 4			34.1, 33.4
Can 5			46.3, 46.8
Can 6			26.2, 22.7
Average	3.5	0.104	34.2
Standard Deviation	---	---	9.1

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* Based on total can contents

TABLE 6

Mineral Content of Canned Spinach Samples

Blanching	Content, mg/100 g wet weight*			
Treatment	Calcium	Magnesium	Phosphorus	Iron
Commercial				
Can 1F	88.0	95.0	40.0	
Can 2F	86.0	91.5	37.0	
Can 3F				4.3
Can 4F				4.4
Hot-Gas				
Can 6A	74.0	99.0	33.5	
Can 6B	69.5	99.0	33.0	
Can 6C				1.3
Can 6D				1.3

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* Based on total can contents

A triangular set of commercially blanched and hot-gas blanched spinach was presented to a panel after the cans had been stored for 10 weeks at room temperature. In a total of 57 judgments obtained in four sessions (using a randomized presentation of the samples) 29 were correct (significant at the p = 0.01 level).

A ranking test of flavor preference using three commercial canned samples and hot-gas blanched spinach (canned under commercial conditions) gave the results tabulated in Table 7.

TABLE 7

Taste Panel Ranking of Three Commercial and One Hot-Gas Blanched Samples of Canned Spinach

Sample	Brine Salt Content %	Cumulative Taste Panel Ranking*
Commercial A	1.16	3.04
Commercial B	0.85	2.62
Commercial C	0.94	2.04
Hot-Gas	0.96	2.38

* 1 = Best Flavor; 4 = Worst Flavor; 56 judgments

Statistical evaluation of the results of the ranking tests (7) showed no significant difference among the four samples.

Green Bean Blanching

The results of short duration runs of hot-gas blanched green beans are tabulated in Appendix B. The canned product preparation conditions and evaluation of green bean samples from short duration hot-gas blanching runs used to establish commercially acceptable conditions are tabulated in Table 8.

TABLE 8

Preparation Conditions and Quality Evaluation of Canned Samples of Hot-Gas Blanched Cut Green Beans

Run No.	Can Size	Brine Temp, ^{o}F	Exhaust Box, ^{o}F	Headspace Vacuum, in. Hg	Quality Evaluation
GB 18	303X 406	190	185	7	Excessive Sloughing
GB 26	303X 406	180	175	6	Excessive Sloughing
GB 29	303X 406	190	-	5	Moderate Sloughing
GB 30	303X 406	190	-	5	Moderate Sloughing
GB 31	303X 406	187	-	6	Moderate Sloughing
GB 34	303X 406	185	-	5	Good Flavor, little sloughing
GB 36	303X 406	180	165	5	No Sloughing
GB 39	603X 700	170	165	5	Too long hold before retorting
GB 40	603X	140	165	4	Good flavor, but "squeeky" or under-blanched
GB 41	603X 700	190	165	5	Overblanched, soft texture
GB 42	603X 700	190	165	7	Good flavor no sloughing

TABLE 8 (Cont'd)

Preparation Conditions and Quality Evaluation of Canned Samples of Hot-Gas Blanched Cut Green Beans

Run No.	Can Size	Brine Temp, °F	Exhaust Box, °F	Headspace Vacuum, in. Hg	Quality Evaluation
GB 43	603X 700	185	160	5	Good flavor, no sloughing
GB 44	603X 700	190	165	6	Good flavor, no sloughing

---

* Thermal process in continuous cooker (252°F, 45 minutes)

The results of long term hot-gas blanching of cut green beans are tabulated in Table 9.

TABLE 9

Long Term Hot-Gas Blanching of Cut Green Beans

Hours of Operation	Feed Wt, lb/hr	Temp, °F	Peroxidase Reduction, %	Wastewater Volume, gal.
1	1620	185	17	-
2	1610	188	17	-
3	-	197	28	-
4	1476	180	33	-
5	-	196	20	-
6	1248	178	18	-
7	-	200	55	-
8	1380	181	51	-
9	-	188	19	0.125
10	1476	184	27	-
11	-	202	54	-
12	1860	182	40	Approx. .026 (Spilled)
13	-	175	83	-
14	-	178	17	-
15	1596	186	43	-
16	-	184	42	-
17	1560	182	51	.03
18	1560	205	44	-
19	1680	180	35	-
20	-	183	23	-
21	-	176	19	-
22	1668	181	26	-
23	-	193	54	-
24	1716	182	45	Sample spilled
25	-	181	37	-
26	1680	176	0	-
27	-	197	40	-
28	-	181	44	-
29	-	189	32	-
30	2004	184	39	-
31	1680	181	30	-

TABLE 9 (Cont'd)

Long Term Hot-Gas Blanching of Cut Green Beans

Hours of Operation	Feed Wt, lb/hr	Temp, °F	Peroxidase Reduction, %	Wastewater Volume, gal
32	-	176	27	.164
33	1156	182	70	-
34	-	187	42	-
35	-	179	33	-
36	1680	181	37	-
37	-	180	62	-
38	-	193	23	-
39	1500	179	33	-
40	-	183	27	0.065
41	1440	182	37	-

The conditions selected for the long term hot-gas blanching of No. 4 sieve size cut green beans was a loading of 3 lb of raw beans/conveyor flight, 185-195°F operating temp, 77 sec residence time and 3% of gauge setting on the steam flow meter which gave 0.633 pounds of steam/min.

The wastewater volume and characteristics for hot-gas blanching of green beans are tabulated in Table 10.

TABLE 10

Wastewater Volume and Characteristics for Hot-Gas Blanching of Green Beans

Sampling Date	Wastewater Volume, gal	Beans Blanched, ton	COD, mg/l	BOD, mg/l	SS, mg/l	pH
8-15	0.125	5.41	2670	1170	143	7.2
8-16	0.056 (approx)	5.39	15500	6380	453	6.8
8-17	-	5.42	-	-	-	-
8-18	0.164	5.76	7260	3530	183	-
8-19	0.065	6.23	17400	6840	550	6.7

The wastewater volume and characteristics for make-up water overflow of the commercial hot-water blancher for cut green beans are tabulated in Table 11.

TABLE 11

Wastewater Volume and Characteristics for Make-up Water Overflow of Commercial Hot-Water Blancher for Cut Green Beans

Sampling Time, hr	Wastewater Volume, gal	Beans Blanched, ton	COD, mg/l	BOD, mg/l	SS, mg/l	pH
8-15						
2	121		11,600	6790	1490	5.9
4	60		15,500	7760	1560	5.6
6	35		15,500	7610	1820	5.0
8	17		13,400	10,500	1870	5.3
Composite	233	14.2	13,900	8510	1810	6.5
8-16						
2	34		13,300	7500	1693	5.1
4	19		13,300	7820	1680	5.4
6	15		13,100	7660	1840	5.2
8	38		8,320	4940	910	5.4
Composite	106	15.6	11,800	7070	1520	-
8-17						
2	24		3,120	1820	144	6.4
4	30		4,780	2610	547	6.5
6	20		2,040	3720	873	6.2
8	18		11,000	6630	613	6.1
Composite	92	19.3	6,600	3850	527	-
8-18						
2	24		4,470	2390	392	6.2
4	17		8,380	4530	667	6.0
6	18		2,500	1300	208	6.2
8	21		-	-	-	-
Composite	80	10.8	5,280	2870	468	-
8-19						
2	22		7,390	4430	650	6.0
4	17		6,780	4020	800	6.1
6	13		8,080	4790	1020	5.9
8	20		7,000	4300	820	6.1
Composite	72	-	7,720	4580	810	-

The headspace gas volume and composition for 603 x 700 cans of green beans are tabulated in Table 12.

TABLE 12

Headspace Volume and Composition for Samples of Canned Cut Green Beans

Sample	Headspace Volume, ml	Percent of			
		N_2	CO_2	H_2	O_2 + Argon
Commercial Blanched	119	90.3	1.1	0.0	8.6
Hot-Gas Blanched	117	86.4	5.0	3.4	5.2

The results of analysis of raw, hot-water and hot-gas blanched samples of green beans for certain vitamins are tabulated in Table 13 and for calcium, magnesium, and phosphorus in Table 14.

TABLE 13

Vitamin Content of Raw and Blanched Green Beans

Sample	Vitamin Content, mg/100g fresh weight			
	B_1	B_2	C	Niacin
Raw	0.077* (0.004)**	0.074 (0.002)	7.3 (0.58)	0.46 (0.01)
Commercially Blanched	0.075 (0.003)	0.059 (0.002)	1.3 (0.60)	0.53 (0.002)
Hot-Gas Blanched	0.068 (0.0007)	0.070 (0.008)	2.2 (1.2)	0.44 (0.00)

---

* Values tabulated are averages of triplicate determinations

** (Standard deviation in mg/100g)

TABLE 14

Mineral Content of Raw and Blanched Green Beans

	Mineral Content - mg/100g		
Sample	Ca	Mg	P
Raw	31.7* (4.2)**	18.9 (3.6)	19.7 (1.6)
Commercially Blanched	35.7 (6.8)	23.6 (3.1)	21.6 (1.8)
Hot-Gas Blanched	37.0 (1.1)	20.2 (1.6)	21.5 (0.0)

---

* Values tabulated are averages of triplicate determinations

** (Standard deviation in mg/100g)

The carotene content of canned green beans found in hot-water and hot-gas blanched samples are tabulated in Table 15.

TABLE 15

Carotene Content of Canned Green Beans (Total Can Contents)

Sample	Carotene Content, mg/100g		
Hot-Water Blanched (Commercial)			
Can 1	0.40,	0.34,	0.35
Can 2	0.33,	0.32,	0.35
Can 3	0.27,	0.25,	0.26
Average		0.32 (S.D. = 0.05)	
Hot-Gas Blanched			
Can 1	0.32,	0.34,	0.39
Can 2	0.32,	0.32,	0.30
Can 3	0.37,	0.37,	0.34
Average		0.34 (S.D. = 0.03)	

The evaluation of hot-gas blanched bean samples for consumer acceptance is an important part of this project. It was possible to arrange for the evaluation of samples of canned cut green beans after various periods of accelerated storage (100°F) by food appraisal specialists at Oregon State University (OSU).

This appraisal was the expert panel type used primarily to determine differences in two food samples. The findings of this panel reflect only indirectly the consumer response to a food sample. The results of the first two evaluations by the 40 member OSU panel after the canned samples had been stored for one and three months are tabulated in Table 16.

TABLE 16

Results of Evaluation of Canned Green Bean Samples

	Mean Scores*							
Blanching Treatment	Appearance		Texture		Flavor		Overall Desirability	
	1 mo	3 mo	1 mo	3 mo	1 mo	3 mo	1 mo	3 mo
Commercial 1	4.82	6.40	4.75	6.22**	4.95	5.65**	4.85	5.65**
Commercial 2	4.07**	5.92	5.05	7.02	4.77	6.75	4.77	6.52
Hot-Gas 1	4.70	6.40	4.60	6.77	4.32**	6.30	4.35	6.30
Hot-Gas 2	4.55	7.45**	5.15	7.00	4.77	6.05	4.80	6.40

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* The higher the score the more preferred the quality factor

** Significantly different from reference or from other samples

Corn-on-cob Blanching

The results of short duration experiments on hot-gas blanching of corn-on-cob are tabulated in Appendix C.

A dozen ears of corn from Run No. COC-20 were tagged and frozen. The following day these ears were tested (with subjective examination) by a group of Agripac, Inc. quality control specialists and compared with commercial blanched frozen ears of corn. The consensus of the evaluation group was that the hot-gas blanched corn would be commercially acceptable but had a distinctly different flavor. A decision was made by Agripac, Inc. management that 40 hours of hot-gas blanching of corn-on-cob could proceed but all product produced must be tagged and segregated after freezing for further quality evaluation after three months of storage. A further condition was that the ears of hot-gas blanched corn be cooled to a temperature as low as the water cooled corn on the commercial line before they were put into the freezer. This condition was met by installing a second cooling water spray manifold and using 5 minutes of spray cooling, 5 minutes of draining and a second 5 minutes of spray cooling. The internal temperature in the cob of hot-gas blanched corn under conditions of Runs No. 20-22 was 150-160°F. After the cooling sequence described above was used, the internal temperature of the cob ranged from 90-110°F; a commercial line sample taken at the end of the water spray cooling had a cob temperature of 124°F. In the initial tests, the bottom of the ears after the first 5 minutes of spray cooling were distinctly warmer than the top. In the long duration runs the ears were rotated 180° as they were held in the 5 minute draining station to achieve uniform cooling.

The results of observations and analyses made during the long duration hot-gas blanching of corn-on-cob are tabulated in Table 17. The conditions used for hot-gas blanching of corn-on-cob were a loading of 240 lb/hr, a temperature range of 210-230°F, a residence time of 14 min and steam injection at the rate of 6.3 lb/min.

TABLE 17

Long Term Hot-Gas Blanching of Corn-on-Cob

Hours of Operation	Temp. °F	Peroxidase Reduction, %	Wastewater Volume, gal
1	219	98	-
2	220	100	-
3	222	92	-
4	210	100	-
5	212	100	-
6	215	98	-
7	220	90	-
8	215	97	7.0
9	218	100	-
10	215	100	-
11	218	87	-
12	220	97	-
13	219	97	-
14	215	100	-
15	220	97	-
16	219	93	16
17	220	98	-
18	223	98	-
19	218	99	-
20	216	98	-
21	225	92	-
22	225	100	-
23	221	100	-
24	225	100	14
25	230	100	-
26	-	100	-
27	-	100	-
28	-	100	-
29	-	100	-

TABLE 17 (Cont'd)

Long Term Hot-Gas Blanching of Corn-on-Cob

Hours of Operation	Temp, °F	Peroxidase Reduction, %	Wastewater Volume, gal.
30	226	100	-
31	222	91	-
32	225	100	14
33	219	100	-
34	217	100	-
35	225	100	-
36	225	100	-
37	221	100	10

The wastewater volume and characteristics measured during hot-gas blanching of corn-on-cob are tabulated in Table 18.

TABLE 18

Wastewater Volume and Characteristics for Hot-Gas Blanching of Corn-on-Cob

Sampling Date	Wastewater Volume, gal	Corn Blanched, ton	COD, mg/l	BOD, mg/l	SS, mg/l
9-18	7	.978	24,850	13,500	2640
9-18	16	.978	23,700	14,200	2920
9-19	14	.978	24,450	15,100	2350
9-19	14	.978	26,350	16,500	2680
9-20	10	.562	23,000	14,200	1200

The wastewater volume and characteristics from the commercial blanching of corn-on-cob are tabulated in Table 19.

TABLE 19

Wastewater Volume and Characteristics for Steam Condensate from Commercial Blancher for Corn-on-Cob

Sampling Time, hr	Wastewater Volume, gal	Corn Blanched, ton	COD, mg/l	BOD, mg/l	SS, mg/l
9-18					
2			19,000	12,500	373
4			22,100	14,400	733
6			24,650	16,800	533
8			20,100	14,200	620
Composite	254	11.5	21,700	15,600	2000
9-18					
2			18,750	12,800	610
4			21,100	14,800	630
6			20,650	13,600	980
8			24,750	16,600	980
Composite	179	11.3	20,550	13,800	740
9-19					
2			15,650	10,500	487
4			13,950	10,700	593
6			23,100	15,400	1500
8			24,150	16,200	1700
Composite	243	11.7	20,100	13,100	1300
9-19					
2			20,850	12,800	1450
4			23,350	14,800	1780
6			19,550	12,500	1980
8			24,600	15,500	2120
Composite	280	8.0	22,890	14,200	1880
9-20					
2			23,100	14,500	770
4			21,350	13,400	830
6			20,750	13,100	890
8			21,700	13,800	940
Composite	304	8.4	21,800	13,800	3190

Samples of frozen corn-on-cob prepared with hot-gas blanching and steam blanching (commercial) were evaluated by a 50-member panel at Oregon State University. The results from this examination are tabulated in Table 20.

TABLE 20

Panel Evaluation of Frozen Corn-on-Cob

Blanching Condition		Mean Scores*			
		Appearance	Texture	Flavor	Overall Desirability
A	Steam	7.18**	5.80	6.40	6.08
D	Steam	7.08**	6.12	5.78	5.72
B	Hot-Gas	6.40	5.26**	5.52	5.12**
C	Hot-Gas	6.50	5.80	6.36	6.02
	LSD	0.55	0.53	0.60	0.55

---

* Hedonic Scale 9 = like extremely; 1 = dislike extremely

** Significant difference

It was noted that sample B was a more mature starchy corn than the other three samples and this is reflected in the lower texture and overall desirability scores.

The vitamin and phosphorus content of samples of raw and blanched corn-on-cob are tabulated in Table 21.

TABLE 21

Vitamin and Phosphorus Content of Raw and Blanched Corn-on-Cob

Nutrient	mg/100g wet weight		
	Raw	Steam Blanched	Hot-Gas Blanched
Vitamin B_1	.121* (.016)**	.157 (.024)	.179 (.007)
Vitamin B_2	.034 (.007)	.034 (.009)	.039 (.002)

TABLE 21 (Cont'd)

Vitamin and Phosphorus Content
of Raw and Blanched Corn-on-Cob

Nutrient	mg/100g wet weight		
	Raw	Steam Blanched	Hot-Gas Blanched
Niacin	1.85* (.10)**	1.85 (.06)	1.91 (.02)
Phosphorus	91.6 (4.2)	85.5 (1.6)	90.1 (2.6)

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* Values tabulated are averages of triplicate determinations
** (Standard deviation in mg/100g)

Beet Blanching

It was possible to develop hot-gas blanching conditions for beets which gave material that peeled satisfactorily and yielded canned product judged by cannery personnel as commercially acceptable. The results of short term experiments on hot-gas blanching of beets are tabulated in Appendix D. Due to an unexpectedly short processing season for beets, it was possible to complete only 19 hours of long duration operation in 1972. The shortened operating season also limited collection of commercial blancher wastewater data, in particular the volume and composition of blancher dump water.

The data collected during the long term hot-gas blanching of beets are tabulated in Table 22. For the long term hot-gas blanching of beets, the residence time

TABLE 22

Long Term Hot-Gas Blanching of Beets

Hours of Operation	Feed Wt, lb/hr	Temp, °F	Peroxidase Reduction, %	Wastewater Volume, gal
1	200	240	100	-
2	-	251	98	-
3	-	245	98	-

TABLE 22 (Cont'd)

Long Term Hot-Gas Blanching of Beets

Hours of Operation	Feed Wt, lb/hr	Temp, °F	Peroxidase Reduction, %	Wastewater Volume, gal
4	-	240	100	10.0
5	-	252	98	-
6	-	255	98	-
7	-	246	98	5.0
8	300	242	96	-
9	300	240	97	-
10	-	248	99	-
11	300	244	98	6.75
12	-	242	98	-
13	-	252	98	-
14	160	247	98	9.3
15	-	247	97	-
16	-	253	98	-
17	200	248	98	-
18	-	250	96	
19	-	241	100	9.25

was 25 min and the steam injection was 4.2 lb/min.

The results of analysis of canned samples of beets for their content of certain vitamins and phosphorus are tabulated in Table 23.

TABLE 23

Vitamin and Phosphorus Content of Canned Beets

	Content, mg/100 g wet weight	
Nutrient	Hot-Water Blanched	Hot-Gas Blanched
Vitamin B_2	.045* (.007) **	.033 (.003)
Vitamin C	3.0 (.22)	2.7 (.40)

TABLE 23 (Cont'd)

Vitamin and Phosphorus Content of Canned Beets

Nutrient	Content, mg/100 g wet weight Hot-Water Blanched	 Hot-Gas Blanched
Niacin	.090 (.007)	.062 (.017)
Phosphorus	97 (7.5)	110 (19.5)

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* Values tabulated are averages of triplicate determinations on samples of beets from three cans

** (Standard deviation in mg/100g)

Electrical, gas and steam flow meters on the hot-gas blancher were used to develop information on power requirements. The energy consumption values obtained during hot-gas blanching of green beans, corn-on-cob, and beets are tabulated in Table 24.

TABLE 24

Energy Consumption during Hot-Gas Blanching of Vegetables

Cumulative Operational Hours	Electrical Energy Used, kwh Blower	 Turbine	 Conveyor Controls	Steam Use, 100 lb	Gas Use, Net Meter Reading
Green Beans					
8.55	33	6	3	3.24	15
16.55	59	12	5	6.27	27
24.43	90	17	7	9.23	40
32.20	118	22	10	12.18	52
41.07	150	28	13	15.55	63
Corn					
8.5	12	4	1	32.3	25
16.0	29	8	2	60.8	29
23.3	40	13	3	88.5	40
32.1	57	17	3.5	121.9	65
37.0	64	21	4	140.4	72

TABLE 24 (Cont'd)

Energy Consumption during Hot-Gas Blanching of Vegetables

Cumulative Operational Hours	Electrical Energy Used, kwh Blower	Turbine	Conveyor Controls	Steam Use, 100 lb	Gas Use, Net Meter Reading
Beets					
7.9	14	5.5	.8	19.9	40
14.4	25	10.7	1.9	36.2	48
19.0	33	18.2	4.9	48.0	56

The cost factors used in computing operational costs were as follows: electrical power, \$.0125/kwh; steam, \$1.00/1000 lb; gas, \$.076/therm with a heat factor of 1.109; and make-up water, \$.10/1000 gal.

DISCUSSION

Any modification in food processing equipment must be rigorously evaluated in terms of reliability, safety, ease of sanitation and maintenance, and cost per unit of material processed. In recent years, the rate of generation of gaseous, liquid and solid by-products as potential contributors to air, water and soil pollution has become an important food processing equipment design criteria. The final product which results from use of modified processing equipment must be at least equivalent in wholesomeness, texture, flavor, appearance and nutritive value to the product prepared with current equipment. During the course of this investigation of in-plant hot-gas blanching of vegetables, all of the above outlined criteria were evaluated albeit at various degrees of completeness.

Liquid Waste Reduction

The prime motivation of this study was the attempt to demonstrate commercial feasibility of a new blanching system which would substantially reduce the volume of liquid wastes now produced during steam or hot-water blanching of vegetables. Therefore, much attention was devoted to measurement of wastewater generation from both the hot-gas blancher and the commercial blanchers. Since the critical evaluation centered on reduction of waste treatment costs possible with the new blanching system, wastewater measurements were made for volume, COD, BOD, SS, and pH. Table 25 gives a summary of the comparisons of wastewater

TABLE 25

Comparison of Wastewater Volume, BOD, COD, and SS from Hot-Gas and Commercial Blanching of Vegetables

Commodity	Wastewater, gal/ton		COD, lb/ton		BOD, lb/ton		SS, lb/ton	
(Date)	Hot-Gas	Comm	Hot-Gas	Comm	Hot-Gas	Comm	Hot-Gas	Comm
Spinach								
3-27	0. 334	741	0. 148	9. 44	-	-	0. 013	0. 450
3-28	0. 216	633	0. 332	8. 32	-	-	0. 012	0. 550
3-29	0. 056	675	0. 050	9. 20	-	-	0. 0019	0. 640
Average	0. 202	683	0. 177	8. 99	-	-	0. 0009	0. 547
Green Beans								
8-15	0. 023	16. 4	0. 00053	1. 9	0. 00023	1. 2	0. 000028	0. 25
8-16	0. 010	6. 8	0. 0013	0. 63	0. 00055	0. 38	0. 000040	0. 086
8-17	-	4. 8	-	0. 26	-	. 15	-	0. 021
8-18	0. 028	7. 4	0. 0017	0. 33	0. 00083	0. 18	0. 000043	0. 029
8-19	0. 010	-	0. 0015	-	0. 00059	-	0. 000048	-
Average	0. 018	8. 9	0. 0013	0. 77	0. 00055	0. 48	. 000040	0. 097
Corn-on-cob								
9-18	7. 2	22. 1	1. 48	3. 98	. 92	2. 87	. 16	. 37
9-19	16. 4	15. 8	3. 23	3. 26	1. 90	1. 82	. 40	. 097
9-19	14. 3	20. 7	2. 92	4. 16	1. 80	2. 26	. 28	. 22
9-20	14. 3	35. 2	3. 13	7. 19	2. 00	4. 16	. 32	. 55
9-21	17. 8	36. 2	3. 42	6. 54	2. 10	4. 17	. 18	. 96
Average	14	26	2. 84	5. 03	1. 74	3. 06	. 27	. 44
Beets								
10-5	14. 2	71	-	-	-	-	-	-
10-6, 10	21. 4	28	-	-	-	-	-	-
10-11	21. 4	26	-	-	-	-	-	-
Average	19. 3	42	-		-	-	-	-

volume and composition between commercial and hot-gas blanching of spinach, green beans, corn-on-cob and beets. For a more facile comparison, the reduction of wastewater volume and lb/ton of COD, BOD, and SS are tabulated on a percentage basis in Table 26.

TABLE 26

Percentage Reduction of Wastewater Volume, COD, BOD, and SS Due to Hot-Gas Blanching of Vegetables

	Percentage Reduction due to Hot-Gas Blanching			
Commodity	Wastewater Volume	BOD	COD	SS
Spinach	99.9	-	98.0	99.8
Green Beans	99.8	99.9	99.8	99.9
Corn-on-cob	46.0	43	44	39
Beets	54.0	-	-	-

It must be emphasized that the percentage reductions shown apply to only one location and it is well known that water usage and waste generation vary over a wide range for different plants processing the same commodity (8). It should be noted that values tabulated for spinach, green beans and beets in Tables 25 and 26 are based on make-up water overflow and do not account for commercial blancher dump water. The values for corn-on-cob do represent total blanching wastewater measurements. In any consideration of the commercial application of hot-gas blanching, it would be necessary to use data on wastewater generation from each individual operation to calculate expected percentage reductions.

It was not possible to evaluate completely the factors of equipment reliability, maintenance, ease of sanitation and safety because the hot-gas blancher used was an experimental design probably quite different from any future commercial unit.

The experimental hot-gas blancher was operated safely during a total of approximately 150 hours of in-plant work. The natural gas furnace had elaborate safety controls and the accumulation of gas, which would represent the major hazard, was highly improbable. The combustion of the natural gas was complete so the formation of carbon monoxide in toxic amounts was highly unlikely.

There was no overt evidence of difficulty in sanitizing the hot-gas blancher. The blancher was operated at a temperature above those tolerant to the growth of microorganisms. There was some sticking to the conveyor belt surface of small pieces of vegetables or their parts (beet hair roots, beet stems, corn silk, etc.). These sticking pieces tended to stay on the belt and gradually dry out and caramelize as the belt recycled through the heated zone. The sticking pieces did not fall off the belt to contaminate freshly blanched vegetables. There was no difficulty experienced in cleaning the wire mesh conveyor belt with small volumes of water after several hours of continuous operation. The hot-gas blancher did not present any unusual maintenance problems during the period of operation.

The quality of final products from hot-gas blanched vegetables was a major concern in this study. The quality evaluation of products from hot-gas blanching was made at three stages. The first stage was subjective examination of freshly blanched material by experienced industry persons. A combination of appearance, feel, taste and color change was used to decide if a sample was adequately blanched. After passing this first screening test, blanched samples were preserved, by use of commercial equipment, as canned or frozen final products. The preserved samples were given a complete quality control test and were examined subjectively for color, flavor and texture by a group of technical and management persons employed by the cannery. This evaluation was the basis for approval to conduct long term runs with hot-gas blanched material returning to the production line. The third stage of evaluation was controlled laboratory organoleptic panel comparison of samples and the sale of products through ordinary commercial channels. This latter form of evaluation was the only possible method for spinach and beets where hot-gas blanched material was mixed with commercially blanched material. For frozen corn-on-cob and canned green beans, the hot-gas blanched portion was kept separate and identified.

The very fact that every commodity studied was accepted for return to production after hot-gas blanching demonstrated the utility of this method with a considerable degree of confidence. The sale of spinach and beets containing mixtures of hot-gas blanched and commercially blanched material has been going on for several months with no adverse consumer response.

The organoleptic evaluation of green beans made by Oregon State University and tabulated in Table 16 indicates that there is no significant difference in overall desirability between hot-gas and hot-water blanched samples. Similar evaluation of frozen corn-on-cob was complicated by maturity difference in the samples. The significantly lower preference for hot-gas blanched corn-on-cob due to difference in appearance may be a deterrent to use of hot-gas blanching of this commodity.

Vitamin and Mineral Retention

One of the expectations for hot-gas blanching when it was first considered was improved retention of water soluble vitamins and minerals due to reduced water leaching. The production of a more nutritious food with hot-gas blanching would justify part of the expense of shifting to this new method. For this reason and due to the need for information on nutrient retention, considerable effort has been devoted to measuring vitamin and mineral content as a function of the type of blanching used.

The results of nutrient retention measurements were tested for significance in those cases where results were available for three or more commodities. The results of nutrient analysis of riboflavin (Vitamin B_2), ascorbic acid (Vitamin C), niacin and phosphorus were subject to randomized complete-block tests using the commodities as blocks and the blanching conditions as treatments. None of the computations produced F-values larger than the tabulated F-values for the appropriate degrees of freedom of the variance ratios. The overall data available to date strongly suggests that there is no significant difference in vitamin and mineral retention when hot-gas blanching is compared to steam or hot-water blanching.

Internal Can Corrosion

An observation made by technicians at Oregon State University who were preparing taste panel samples of canned green beans held at 100°F for three months has led to a more detailed study of the extent of internal can corrosion by Agripac, Inc. and their container supply company. Sets of ten 603 x 700 cans each of hot-water and hot-gas blanched green beans were opened at 54°F after five months of warehouse storage. The extent of corrosion was rated from visual inspection by experienced persons from a container supply company on a scale of 1 = no corrosion and 10 = detinned completely. The set of hot-water blanched bean cans showed an average corrosion number of 4.5 compared to a corrosion number of 2.3 for cans used for hot-gas blanched beans. These observations of corrosion differences are being further evaluated over the normal shelf life period of 18 months. If the extent of corrosion continues to be lower in hot-gas blanched bean cans, a considerable saving in container costs could help to justify commercial use of hot-gas blanching.

Operational Cost of Hot-Gas Blanching

In any consideration of new processing technology, the cost of operation per unit of production is one of the most important factors in decision-making. It was possible to get exact operating costs for the experimental hot-gas blancher by metering power and steam use. Table 27 tabulates the dollar cost per ton of vegetable blanched for hot-gas, steam and hot-water blanching of four vegetables.

TABLE 27

Operation Cost of Blanching Vegetables

Commodity	Cost (dollars)/Ton Blanched Hot-Gas	Steam	Hot-Water
Spinach*	2.01	-	.22
Green Beans	0.27	-	.32
Corn-on-Cob	4.75	1.26	-
Beets	5.39	-	.52

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* Electrical cost estimated from power ratings of motors, no steam used

This estimate for steam and hot-water blanching was made using published steam requirements for blanchers (9), cost of operation of conveyor drive motors, cost of make-up water, and rate of raw products introduction from in-plant observations.

Only in the case of green bean blanching is the operation cost of hot-gas blanching competitive with commercial blanching costs. The high operational costs for corn-on-cob and beet blanching is due to the light loading, long residence time and high steam injection requirements. The operational cost for hot-gas blanching of spinach is a factor of ten higher than hot-water blanching and the increased cost could only be justified by offsetting savings in waste disposal costs. It is expected that some reduction of cost/ton for hot-gas blanching would result from increased efficiency of a commercial-scale unit compared to the experimental unit. A major reduction in operational cost would result if dehydration of the hot-gas blanched material was accepted since this would lower steam cost. It is likely that partially dehydrated beets would recover their water content after canning. Partially dehydrated corn-on-cob may recover water during spray cooling. Neither of these possibilities have been examined as yet. If it were possible to accept partial dehydration of vegetables during hot-gas blanching, both operational costs and cost of wastewater treatment would be substantially reduced.

ACKNOWLEDGMENTS

We are indebted to the Office of Research and Monitoring, U. S. Environmental Protection Agency for providing a major share of the funding of this study under Grant S 800250. We express our sincere appreciation to the EPA Project Officers, Kenneth A. Dostal and Harold W. Thompson for many helpful suggestions during planning, data collection and reporting of results.

We thank Michael T. Soderquist and his colleagues at Oregon State University for the BOD, COD, and SS determinations on samples collected during experimental work at Corvallis.

The in-plant operations would not have been possible without the permission and constant advice and assistance of management, production and technical persons at two canneries. While it is not possible to acknowledge by name the large number of persons who made direct contributions to the installation, operation, and product evaluation phases of the in-plant work, a number of key persons must be mentioned. At Tillie Lewis Food, Inc. in Stockton, California the following persons were extremely helpful: Harry Rosen, Rex Defenbaugh, Clair Weast, Max Nicholson and Andy Dillman. At Agripac, Inc. (Salem, Eugene, Corvallis, Oregon), E. I. Pitkin, George Henken, Alton McCully, Donald Walker, Gary Lewis, Robert Isaac and Gene Parrish were instrumental in the accomplishment of the in-plant blanching of green beans, corn-on-cob, and beets.

Many of the Oregon State University faculty provided advice and direct assistance to the work in Corvallis, especially Darrell Beavers, Robert Cain, Howard Milleville, Lois McGill and Michael Soderquist.

We thank Magnuson Engineers, Inc. of San Jose, California for loaning us pieces of ancillary equipment during spinach blanching.

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APPENDIX A.

Short Duration Hot-Gas Blanching of Spinach

Run No.	Feed Wt, lb	Product Wt, lb	Temp, °F	Residence Time, sec	Peroxidase Inactivation, %
TLSP-1	10	6	240-250	154	99
TLSP-2	9	5	240-250	183	99
TLSP-3	8.5	4.5	235-245	210	99
TLSP-4	8.7	4.8	240-250	330	99
TLSP-5	10.5	6.5	245-250	144	99
TLSP-6	10.5	6.5	235-250	83	94
TLSP-7	8.5	5.0	240-250	108	99
TLSP-8	200	180	220-250	108	99

APPENDIX B.

Results of Short Duration Runs of Hot-Gas Blanching of Cut Green Beans

Run No.	Lb/Flight Feed Wt, lbs	Product Wt, lbs	Temp, °F	Residence Time, Sec	Peroxidase Reduction, %	Steam Meter, %
GB 1	$\frac{2}{11.0}$	9.0	250	183	66	0*
GB 2	$\frac{2}{11.5}$	9.0	250	183	80	25*
GB 3	$\frac{2}{11.5}$	6.0	250	330	96	50*
GB 4	$\frac{2}{12.0}$	10.8	238-246	144	100	(70 psig)**
GB 5	$\frac{2}{19.4}$	20.4	230-242	82	96	(70 psig)**
GB 6	$\frac{2}{20.8}$	20.8	240-245	82	98	(70 psig)**
GB 7	$\frac{2}{19.0}$	18.8	235-250	82	99	(70 psig)**
GB 8	$\frac{2}{13.0}$	12.5	235-250	82	96	(70 psig)**
GB 9	$\frac{2}{21.2}$	20.7	218-225	82	98	(85 psig)**
GB 10	$\frac{1}{18.7}$	18.4	230-240	73	99	(80 psig)**
GB 11	$\frac{2}{19.5}$	19.0	230-245	73	98	(80 psig)**
GB 12	$\frac{3}{19.8}$	19.5	230-240	73	98	(80 psig)**

APPENDIX B. (Cont'd)

Results of Short Duration Runs of Hot-Gas Blanching of Cut Green Beans

Run No.	$\frac{\text{Lb/Flight}}{\text{Feed Wt, lbs}}$	Product Wt, lbs	Temp, °F	Residence Time, Sec	Peroxidase Reduction, %	Steam Meter, %
GB 13	$\frac{4}{20.8}$	20.8	230-240	73	96	(80 psig)**
GB 14	$\frac{4}{27.0}$	24.8	225-235	73	97	(60 psig)**
GB 15	$\frac{4}{20.0}$	19.8	240-245	73	96	(50 psig)**
GB 16	$\frac{4}{22.5}$	22.0	235-240	73	99	(70 psig)**
GB 17	$\frac{4}{20.4}$	20.3	230-240	73	98	(40 psig)**
GB 18	$\frac{3}{23.0}$	23.0	230-240	73	99	(40 psig)**
GB 19	$\frac{4}{23.0}$	23.0	225	73	98	(40 psig)**
GB 20	$\frac{4}{22.7}$	22.8	230	77	95	(40 psig)**
GB 21	$\frac{4}{21.2}$	22.5	230	77	-	(40 psig)**
GB 22	$\frac{4}{23.0}$	22.8	220-230	77	80	(40 psig)**
GB 23	$\frac{4}{21.8}$	23.5	240-250	77	87	(40 psig)**
GB 24.	$\frac{4}{18.2}$	18.5	250-260	77	86	(40 psig)**

APPENDIX B. (Cont'd)

Results of Short Duration Runs of Hot-Gas Blanching of Cut Green Beans

Run No.	Lb/Flight Feed Wt, lbs	Product Wt, lbs	Temp, °F	Residence Time, Sec	Peroxidase Reduction, %	Steam Meter, %
GB 25	6 21.3	22.4	220-225	77	87	(30 psig)**
GB 26	6 22.5	22.3	220-225	77	-	(30 psig)**
GB 27	6 21.8	22.1	220-225	77	63	(20 psig)**
GB 28	6 20.1	21.1	225	77	0	(10 psig)**
GB 29	4 22.2	23.5	225-230	77	61	(20 psig)**
GB 30	4 20.0	20.5	225-230	77	-	(20 psig)**
GB 31	4 19.9	20.5	225	77	-	(10 psig)**
GB 32	4-5 20.0	21.0	230	77	0	4***
GB 33	4-5 20.8	21.2	250	77	9	4***
GB 34	4-5 20.5	21.0	230	77	19	4***
GB 35	3 22.6	22.0	222-225	77	59	4***
GB 36	3 22.1	22.3	199-201	77	21	4***

APPENDIX B. (Cont'd)

Results of Short Duration Runs of Hot-Gas Blanching of Cut Green Beans

Run No.	Lb/Flight / Feed Wt, lbs	Product Wt, lbs	Temp, °F	Residence Time, Sec	Peroxidase Reduction, %	Steam Meter, %
GB 37	3 / 23.0	23.4	175-180	77	0	4***
GB 38	3 / 18.4	18.7	165-171	77	0	4***
GB 39	3-4 / 25.7	26.3	185	77	22	3***
GB 40	3+ / 26.4	26.6	193-195	77	-	3***
GB 41	3 / 29.0	28.7	182-195	77	34	3***
GB 42	3 / 27.5	28.3	184-190	77	0	3***
GB 43	3 / 26.5	26.8	185-191	77	7	3***
GB 44	3 / 27.7	27.9	188-196	77	12	3***

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* Steam flow meter rated at 2.1 lb/min at 100% of scale

** Steam pressure gauge reading made during temporary closing of inlet steam valve

*** Steam flow meter rated at 21 lb/min at 100% scale

APPENDIX C.

Results of Short Duration Runs for Hot-Gas Blanching of Corn-on-Cob

Run No.	Lb/Flight Feed Wt,lb	Product Wt., lb	Temp, °F	Residence Time, Min	Peroxidase Reduction, %	Steam Meter, %
COC-1	$\frac{4.5}{19.5}$	19.3	265	8	-	3***
COC-2	$\frac{4.5}{21}$	20.5	280	8	53	3
COC-3	$\frac{4.5}{20.3}$	19.7	310	10	-	5
COC-4	$\frac{4.5}{19.8}$	18.8	250	19	-	10
COC-5	$\frac{4.5}{20.6}$	19.9	235	19	100	10
COC-6	$\frac{4.5}{21.6}$	19.5	210	37	96	4
COC-7	$\frac{4.5}{21.1}$	20.6	220	13	90	10
COC-8	$\frac{4.5}{20.2}$	20.3	206	13	96	10
COC-9	$\frac{4.5}{19.9}$	19.6	210	16.5	92	8
COC-10	$\frac{4.5}{20.3}$	20.0	225	16.5	100	10
COC-11	$\frac{4.5}{20.3}$	19.7	215	16.5	83	13
COC-12	$\frac{4.5}{21.9}$	21.2	220	16.5	95	10

APPENDIX C. (Cont'd)

Results of Short Duration Runs for Hot-Gas Blanching of Corn-on-Cob

Run No.	Lb/Flight Feed Wt, lb	Product Wt., lb	Temp, °F	Residence Time, Min	Peroxidase Reduction, %	Steam Meter, %
COC-13	4.5 21.4	20.5	220	16.5	95	10
COC-14	4.5 21.6	21.0	225	15	97	15
COC-15	4.5 22.0	21.8	225	15	96*	25
COC-16	4.5 21.6	20.9	230	17	*	23
COC-17	4.5 17.7	21.0**	215	12.8	92*	30
COC-18	4.5 19.7	20.4**	215	10	82*	30
COC-19	4.5 20.1	21.4**	215	11.3	95*	30
COC-20	4.5 20.9	22.1**	215	12.5	78	30
COC-21	4.5 21.0	22.2**	220	12.5	97	30
COC-22	4.5 19.4	20.6**	220	12.5	93	30

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* Catalase test negative

** After cooling with water sprays

*** Steam flow meter rated at 21 lb/min at 100% scale

APPENDIX D.

Short Duration Hot-Gas Blanching of Beets

Run No.	Feed Wt, lb	Product Wt, lb	Temp, ^{o}F	Residence Time, min	Steam Flow, lb/min	Peroxidase Reduction, %
B-1	20	18.5	250-270	5.5	70**	Underblanched
B-2	20	16.5	255-280	6.5	40**	Underblanched
B-3	20	19.5	255-270	2.4	40**	Underblanched
B-4	20	17.8	255-270	6.5	100**	Good peel, loosening
B-5	20*	18.5	250-262	18.5	80**	Underblanched, soft peel
B-6	14	11	245-254	14	2.1	Good peel, loosening
B-7	22	17.5	235-252	14	4	99.9
B-8	20.2	17.1	230-242	14	10	--
B-9	20.7	16.6	215-233	14	9.8	--
B-10	49	42.5	174-189	21	2.1	100
B-11	47	46.5	272-280	1	2.1	0
B-12	44	39.3	182-190	30	1.0	95
B-13	49.4	47.0	177-178	20	1.0	--
B-14	40	38.5	176-180	20	1.0	95
B-15	21	19.5	230-240	8	0.8	73
B-16	24.3	22	232-245	14	0.8	99

APPENDIX D. (Cont'd)

Short Duration Hot-Gas Blanching of Beets

Run No.	Feed Wt, lb	Product Wt, lb	Temp, °F	Residence Time, min	Steam Flow, lb/min	Peroxidase Reduction, %
B-17	18.5	17.5	235-240	14	2.1	Underblanched
B-18	21.3	19	245-250	16	4.8	91
B-19	20	18.1	250	20	4.8	96
B-20	22.2	19.5	238-252	23	4.8	100
B-21	23.5	20.8	235-250	26	4.2	99
B-22	20.0	18.0	245-255	25	4.2	99
B-23***	41	41.0	235-250	26	4.2	--

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* Large beets used

** Steam pressure gauge reading made during temporary closing of inlet steam valve

*** Beets put through peeling line during plant lunch break, canned for evaluation

CONCENTRATION OF BREWERY SPENT GRAIN LIQUOR USING A SUBMERGED COMBUSTION EVAPORATOR

by

J. L. Stein, J. H. Dokos, T. Brodeur, and M. R. Radecki*

INTRODUCTION

The brewing industry in the United States operates some 130 breweries across the country and produces approximately 133,000,000 barrels of beer per year. The effluent control problems of the industry have been accentuated in recent years due to the closing of many small outmoded breweries in large metropolitan areas coupled with the construction of large, more modern breweries in smaller cities and towns. This trend has resulted in increased percentages of brewery wastewaters in the influent of many municipal treatment plants which have had little or no experience in the treatment of high carbohydrate wastes.

BREWING INDUSTRY WASTEWATER PROBLEM

A process flow diagram for a typical brewery is shown on Figure 1. Malt is crushed into fine particles and mixed in aqueous solution. A similar process is carried out with the grain adjunct (rice, corn or other grain derivative), except that the adjuncts are heated and brought to a boil before being combined with the malt. The soluble fractions are separated, and the starches are converted to sugars and the proteins into amino acids. Upon completion of the mashing operation the grain solids are separated from the malt extract, or wort. The spent grains are then normally screened and mechanically pressed to remove as much moisture as possible. The grain is then fed to a rotary kiln dryer and the dried grain is then ready for shipment to cattle feed processors. The wort is sent to the brew kettle where it is boiled and mixed with hops. All enzymes are destroyed and the resins which impart flavor are extracted from the hops. Following this operation, the hops are screened from the wort and either mixed in with the spent grains or disposed of separately. The hot wort is then cooled and prepared for fermentation. Proteins which were coagulated in the brew kettle settle to the bottom of the wort receiver and become known as trub. The trub may be mixed with spent grains, hauled to a landfill, or sewered.

Fermentation of the wort is then initiated with the addition of yeast. Sugars are converted to alcohol and carbon dioxide, and an excess of yeast is produced. Carbon dioxide may be recovered for counter-pressurization of lager tanks and possibly for carbonation of the beer further along in the process, or it may be drawn off for sale with any excess vented to the atmosphere. The yeast may be reused several times before it is discarded. Upon completion of fermentation, the beer is ready for aging and

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* All employees of Anheuser-Busch, Inc., St. Louis Missouri

THE BREWING PROCESS

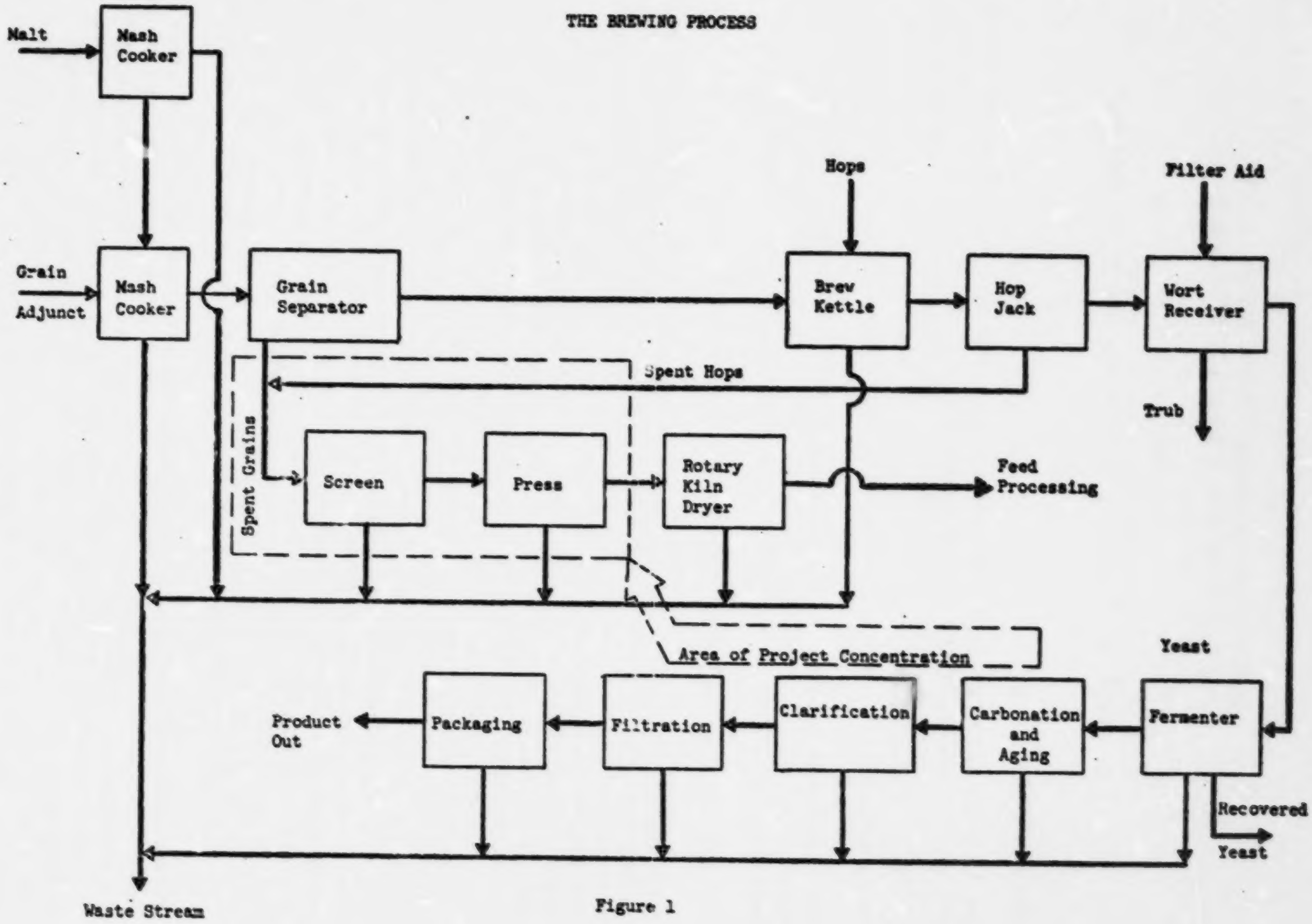
Malt
Mash Cooker
Grain Adjunct
Mash Cooker
Grain Separator
Hops
Brew Kettle
Hop Jack
Filter Aid
Wort Receiver
Trub
Spent Hops
Spent Grains
Screen
Press
Rotary Kiln Dryer
Feed Processing
Area of Project Concentration
Yeast
Fermenter
Recovered Yeast
Carbonation and Aging
Clarification
Filtration
Packaging
Product Out
Waste Stream

Figure 1

additional carbonation, brought about by injection with carbon dioxide or through a second fermentation step. The beer is then clarified and filtered, using either cotton or diatomaceous earth filters. Following this step, the beer is ready for packaging.

The principal waste streams resulting from this process are as follows:

1. Washings from the numerous cookers, kettles, holding tanks, fermentation tanks, storage tanks, and piping.
2. Screen and press liquor from the spent grains drying operation (if grains are not sold "as is" for animal feed or sent to an independent dryer).
3. Trub (if not added to spent grain).
4. Spent yeast (if not added to spent grain).
5. Clarification precipitates (if not added to spent grain).
6. Spent filter aid or washings from cotton pads.
7. Beer overflows and spills from packaging operation.
8. Spent cleaning solutions.

The characteristics of the combined brewery waste stream are highly variable, both from plant to plant and within a specific brewery. The wastes from different plants vary depending upon the raw materials used, process equipment employed, residual disposal techniques, etc. The effluent from a particular plant may vary as a function of which of the various processes are operating at any particular time. Generally speaking, brewing wastes are abundant in degradable organic matter and contain abundant amounts of suspended and dissolved solids. Variability in the amounts of biochemical oxygen demand ($B.O.D._5$) and suspended solids contained in the wastewater is caused by the numerous batch processes involved in brewing.

Due to the variability and strength of brewery wastewaters, successful conventional treatment of these wastes alone using trickling filters and/or activated sludge has been difficult and costly to achieve. Most breweries have long recognized the benefits to be realized by combining their wastes with domestic sewage, and the practice of combined treatment is widespread. (Only two breweries in the United States operate their own treatment facilities.) Different treatment plant operating techniques are needed, however, as the proportion of brewing wastes, as with many other wastes, increases in the total volume of waste handled by the municipal treatment plant. Virtually all treatment plants today also find themselves being required to meet more stringent effluent standards, and, hence, are going "upstream" in an effort to reduce the total load on their facilities.

SPENT GRAIN LIQUOR

One of the most significant sources of high strength organic wastes in the brewing industry is the liquor resulting from the spent grains recovery process. In this process, waste grain from the mashing process is screened and pressed to remove as much moisture as possible by mechanical means, and then dried to produce saleable animal feed. The liquor remaining from the screening and pressing operations is characteristically high in $B.O.D._5$ and suspended solids, and somewhat variable as to the ratio of soluble to insoluble solids. Breweries with grains drying operations can usually attribute 30 to 60 percent of their total $B.O.D._5$ and suspended solids discharge to screen and press liquor. Attempts to eliminate the grain liquor problem to date have been limited in their success. Some breweries have eliminated their drying operations and sell their grains wet. Wet grain feeding operations can, however, become nuisances. When grains are hauled to an independent drying operation the spent liquor problem has only been moved, not eliminated. Brewers, then, have been forced to look at means for recovering the spent grain liquor and attention has focused on concentration processes.

The use of a liquor concentration process would allow the actual elimination of the grain liquor as a waste stream. All waste grain materials could be dried and sold as a by-product. The development of such a process could lead to significant waste strength reductions throughout the industry.

PROCESS SELECTION

The decision of Anheuser-Busch to proceed with full scale investigation of a method of solids concentration using submerged combustion evaporation was based upon compatibility with existing grain drying and recovery equipment and the success of preliminary pilot plant investigations. Prior to the commencement of the design of a full-scale submerged combustion system several other methods for the disposal of the spent grain liquor were explored. These approaches involved the use of a dry grain recycle system and a number of evaporative systems. One system involved the elimination of screening or pressing of the grain; the wet grain would be mixed with dry recycled grain and then added to the dryer. This process required considerable additional dryer capacity coupled with greatly increased fuel costs. A modification was examined in which the grain would be screened but not pressed prior to mixing with the recycled grain. An evaporator of the submerged combustion type would be used to concentrate the screened liquor so that it could also be mixed with the recycled material. This process showed considerable merit for new installations, but not for existing plants where the added dryer capacity would be difficult to install and presses were already in place.

Two systems were studied which would be directly applicable to existing plants. The first involved the use of a centrifuge to remove the suspended material from the screen and press liquor prior to evaporation in a conventional triple-effect evaporator. The second utilized a vibrating screen to remove coarse solids from the spent liquor before adding the liquor to a submerged combustion evaporator. The triple-effect evaporation system was estimated to be more costly to install than the submerged combustion type, but slightly less expensive to operate. Questions arose, however, concerning the ability of the conventional evaporator to tolerate the suspended solids in the spent liquor, as well as the ability of either centrifuges or screens to reduce the suspended solids concentration to an acceptable level. It was concluded that the submerged combustion system could offer the greatest degree of reliability and the lowest cost, and additional research was directed toward this area.

PILOT PLANT STUDIES

Preliminary studies to determine the practicality of the process and to identify potential problem areas were conducted in May, 1970, by the Anheuser-Busch Technical Center. A pilot plant evaporator and a vibrating screen were obtained in order to carry out these studies. A series of twelve tests was run with the 24-inch vibrating screen. These tests indicated that the minimum required concentration of 20 percent solids could be guaranteed for most feed conditions and that concentrates in the 30-35 percent solids range might be obtainable.

The studies showed that the feed soluble-insoluble solids ratio should be maintained above 1.0 to avoid stack plugging and entrainment of solids. It was found that foaming was dependent on concentration and at concentrations of 7 to 10 percent excessive foaming ceased. Burning of grain was not a significant problem due to the small amount of surface area available. It was considered that there would be no problem in removing what grain material was burned and that the amount of material would be insignificant in any event. It was also determined that the evaporator would not violate any existing air pollution regulations. Odors were detected in the pilot plant operation, but it was felt that these should be localized in nature.

FULL SCALE DEMONSTRATION

Based upon the success of the pilot studies, a decision was made to design a full scale evaporator installation and to seek a Research/Development/Demonstration grant from the Environmental Protection Agency. The grant was approved and a complete testing and evaluation program was set up. The Houston Brewery of Anheuser-Busch, Inc., was selected as the test site.

The system as designed following the pilot plant work is shown in Figure 2. Cooked grain mash is dumped into the grain separator, where the wort used to make the beer is drawn off. Water under high pressure is then used to force the grain from the grain separator to a dewatering screen and then to a holding tank. Water from the first six minutes of washing, which is high in B.O.D.$_5$ and suspended solids, is recycled to the holding tank because it is impractical to by-pass the screen or to carry the rinse water to the SWECO screen which is located in another building. The remainder of the wash water is sufficiently clean to be sent directly to the sewer. Wastes from the brewing operation, such as spent hops, are also sent to the holding tank.

The contents of the holding tank are then pumped to a dewatering screen ahead of the spent grain holding tank. The spent grains are then sent to a series of presses for further dewatering. Liquor from the dewatering screen and the presses is delivered to a common sump, and then sent through the SWECO dewatering screen. Here large particles which have passed through the presses are recovered, and along with any other recoverable

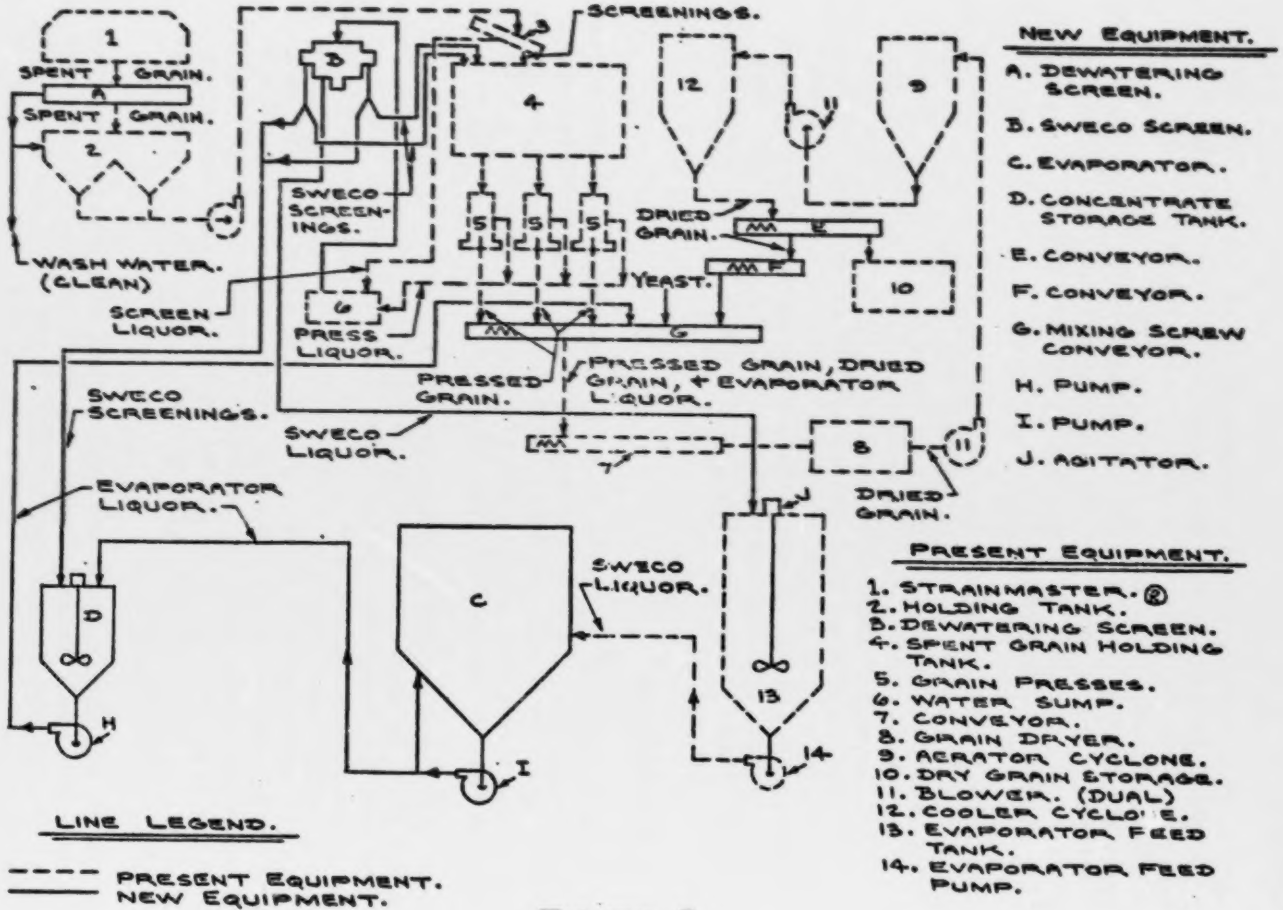
1
SPENT GRAIN.
A
SPENT GRAIN.
2
WASH WATER. (CLEAN)
SCREEN LIQUOR.
B
SWECO SCREENINGS.
3
SCREENINGS.
4
5
5
5
6
PRESS LIQUOR.
YEAST.
DRIED GRAIN.
E
F
G
PRESSED GRAIN.
PRESSED GRAIN, DRIED GRAIN, + EVAPORATOR LIQUOR.
SWECO SCREENINGS.
SWECO LIQUOR.
7
8
9
10
11
11
12
13
14
DRIED GRAIN.
EVAPORATOR LIQUOR.
D
H
C
I
SWECO LIQUOR.
J
NEW EQUIPMENT.
A. DEWATERING SCREEN.
B. SWECO SCREEN.
C. EVAPORATOR.
D. CONCENTRATE STORAGE TANK.
E. CONVEYOR.
F. CONVEYOR.
G. MIXING SCREW CONVEYOR.
H. PUMP.
I. PUMP.
J. AGITATOR.
PRESENT EQUIPMENT.
1. STRAINMASTER.®
2. HOLDING TANK.
3. DEWATERING SCREEN.
4. SPENT GRAIN HOLDING TANK.
5. GRAIN PRESSES.
6. WATER SUMP.
7. CONVEYOR.
8. GRAIN DRYER.
9. AERATOR CYCLONE.
10. DRY GRAIN STORAGE.
11. BLOWER. (DUAL)
12. COOLER CYCLONE.
13. EVAPORATOR FEED TANK.
14. EVAPORATOR FEED PUMP.
LINE LEGEND.
---- PRESENT EQUIPMENT.
—— NEW EQUIPMENT.

FIGURE 2

suspended matter, are returned to the spent grain holding tank for recycle. Alternately, these solids may be sent to the concentrate storage tank.

Liquor from the SWECO screen is sent to the evaporator feed tank, where it is agitated until being sent to the evaporator itself. In the evaporator the solids content of the liquor is brought to the 20-25 percent range. The concentrate is then delivered to the concentrate storage tank where solids from the SWECO screen may be added.

This concentrate is then delivered to a mixing screw conveyor where it is combined with the spent grain pressings, spent yeast, beer clarification precipitate (if available) and recycled dry grain, and then sent to the grain dryer. Once the grain has left the dryer, it is then cooled and ready for recycle or shipment as Brewers Dry Grain.

Principal items of new equipment for the process include the SWECO screen and the submerged combustion evaporator. The SWECO screen is a 60-inch unit with two decks. The top deck is a 30-mesh screen and the lower deck is a 74-mesh screen. The SWECO unit was chosen over other types because of the extensive experience Anheuser-Busch has had with the screen. The evaporator chosen was not of the same design as that used in the preliminary studies. A 25 million BTU/hr unit manufactured by Thermal Research and Engineering Corporation, Conshohocken, Pennsylvania, was selected for reasons of lower first cost and fire safety features. The evaporator tested uses natural gas only as a fuel, although burners are available which will burn gas and No. 2 oil. The evaporator is shown in Figure 3.

Table 1 summarizes the test runs of the submerged combustion evaporator. The first problem which arose was a very poor heat efficiency caused by the use of a single-pass water cooling system for controlling the skin temperature of the burner downcomers. Initial attempts to solve this problem resulted in such high skin temperatures that rapid metal fatigue occurred. This was finally overcome with the design shown in Figure 4. This design provides dilution air to the downcomer which keeps the skin temperature down without sacrificing efficiency.

EFFLUENT STRENGTH REDUCTION

Initial plans called for a long term study of the brewery effluent both with and without the benefit of the spent liquor evaporator. The decision to use only one burner and downcomer at a time during the latter stages of the development phase has restricted the amount of the spent grain liquor which the evaporator can concentrate.

Therefore the effects of having an evaporator installation sufficient to concentrate all the spent grain liquor cannot presently be measured. The approximate effect, however, can be determined by deducting the pollutant load from the spent grain liquor, using established data, from the measured pollutant load from the brewery without evaporation of the liquor. This calculation is shown in Table 2 for the Houston Brewery.

Projected reductions in B.O.D.$_5$, C.O.D. and suspended solids are all quite significant. Modification of the evaporator in the first half of 1973 to bring it up to full capacity will allow an exact determination of the effluent strength reduction brought about by recovery of the spent grain liquor.

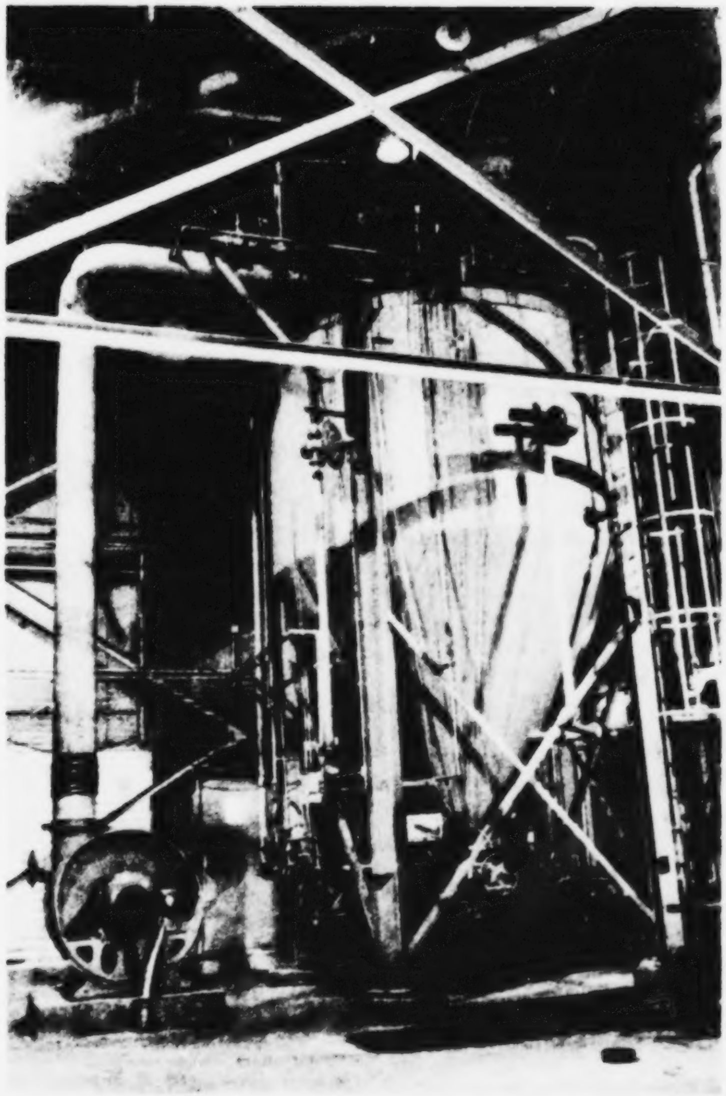

FIGURE 3. SUBMERGED COMBUSTION EVAPORATOR

TABLE 1

TEST RUNS OF SUBMERGED COMBUSTION EVAPORATOR

No.	Date	Firing Rate, Millions of BTU/hour	Feed Rate, Gallons per minute	Feed Concentration, % Total Solids	Product Concentration, % Total Solids	Downcomer Design	Results
1	4/6/71 - 4/23/71	25.0-27.5	Flowmeter out of Service	2.4-3.2	20-25	316 Stainless Steel Single-pass water cooled	35% of input heat lost to sewer
2	5/10/71 - 5/17/71	27.8	35	Same as above	20-25	Same as above	16% of input heat lost to sewer. One burner tip broken off.
3	9/2/71 - 9/10/71	25.0-26.0	40-50	Same as above	18-20	316 Stainless Steel Therminol 66 cooled from condensate bath	Therminol temperature came up to maximum recommended level in 48 hours. Burnt liquor coating on downcover weirs formed insulator. Baffle plates on bottom of downcomers loosened.
4	10/4/71 - 10/7/71	25.5	38	Same as above	22	316 Stainless Steel Non-jacketed	Both downcomers buckled due to excessive heat
5	12/4/71 - 12/16/71	18.0	34	Same as above	20-22	Inconel 601 (1) Non-jacketed (1) Air-cooled	Weld split on non-jacketed downcomer. Tip broken off on air-cooled downcomer.
6	1/4/72 - 1/27/72	14.0-16.0	25-27	Same as above	21	Same as above but no tips	Hole burned through non-jacketed downcomer. Several holes in air-cooler downcomer and large bulge on side.
7	8/16/72 - 10/14/72	9.0-11.9*	21	Same as above	20	Inconel 601 Air-cooled with dilution air	Could not reach 12.5 million BTU/hour
8	10/19/72 - 11/10/72	12.3-12.5*	24.5	Same as above	20	Same as above but with pressure differential controller on input to main blower.	No Problems.
9	11/30/72 - Present	12.5*	24.5	Same as above	20	Same as above	No Problems.

* Only one burner in use.

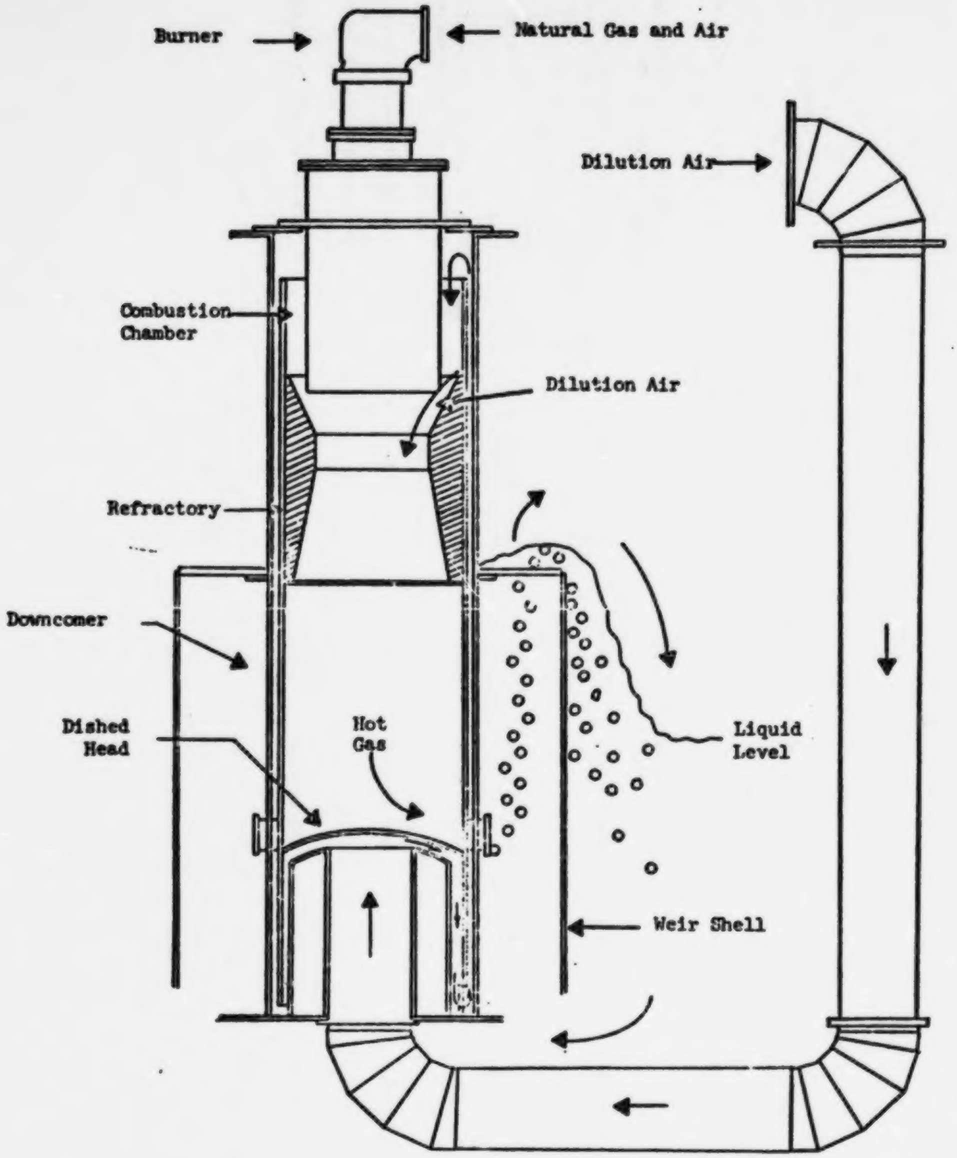
Burner
Natural Gas and Air
Dilution Air
Combustion Chamber
Dilution Air
Refractory
Downcomer
Dished Head
Hot Gas
Liquid Level
Weir Shell

FIGURE 4 - FINAL DOWNCOMER DESIGN

TABLE 2 - PROJECTED EFFLUENT IMPROVEMENT

	Flow mgd	BOD_5, mg/1	BOD_5, #/day	COD mg/1	COD #/day	S.S. mg/1	S.S. #/day
Total Effluent With Liquor	1.96	1,760	28,770	3,040	49,690	850	13,890
Spent Grain Liquor	0.08	18,750	12,510	38,150	25,450	12,550	8,370
Total Effluent Without Liquor	1.88	1,040	16,260	1,550	24,240	350	5,520
Percent Reduction	4.08	40.9	43.5	49.0	51.2	58.8	60.3

ECONOMICS

Table 3 shows the estimated capital and operating costs of an evaporation system designed for a brewery having a production capacity of 2,000,000 barrels per year. Two conditions are illustrated, one using low cost fuel, assumed to be natural gas at 20¢ per million BTU, and the other using relatively high cost fuel, such as natural gas at 80¢ per million BTU or No. 2 oil at 16¢ per gallon. The value assumed for low cost fuel is typical for those areas where natural gas has historically been readily available and there have been few, if any, interruptions to industrial customers. The value assumed for high cost fuel would apply to those areas where natural gas is not available to industrial customers on a year-round basis. This figure allows for an equivalent amount of No. 2 oil to be burned during gas interruption or at all times if necessary.

For each condition two cases are illustrated. The first case utilizes a submerged combustion evaporator system as demonstrated. The second case involves the use of a conventional multiple-effect evaporator with solid bowl centrifuges provided to reduce the suspended solids load and thereby minimize the fouling potential. Two systems such as these have recently become operational in U.S. breweries.

The R.O.I. (Return on Investment) percentages calculated in Table 3 indicate that submerged combustion is the process of choice where low-cost fuel is available. The return is attractive enough on the investment to suggest its funding irrespective of pollution control consideration. A far different situation is presented for the case of high cost fuel. Here neither submerged combustion nor conventional evaporation can be economically justified on the basis of product recovery alone. In cases where some type of control system is mandatory to reduce waste loadings, conventional evaporation would be far less costly due to its greater efficiency.

CONCLUSIONS

Based upon the research and development conducted to date the following conclusions can be drawn:

1. Spent grain liquor can be a significant source of pollution in brewery wastewaters.
2. Spent grain liquor can be successfully concentrated in a submerged combustion evaporator. Foaming and fouling are not significant problems, and extensive pre-treatment of the liquor is not mandatory.
3. Submerged combustion evaporation is economically attractive in low-cost fuel areas, but high cost fuels tend to rule out the process in favor of conventional evaporative processes. Where high cost fuels must be used the efficiency of the conventional evaporator becomes more important than the capital costs associated with the more extensive conventional evaporative and pretreatment equipment.

TABLE 3 ECONOMICS OF ADDING SPENT GRAIN LIQUOR CONCENTRATOR TO EXISTING DRYING OPERATION

	Low Cost Fuel		High Cost Fuel	
	Submerged Combustion	Multiple-Effect	Submerged Combustion	Multiple-Effect
Capital Cost	$425,000	$680,000	$425,000	$680,000
Annual Yield of Additional Dried Grain @ $50.00/Ton	226,800	226,800	226,800	226,800
Incremental Costs of Operating Concentrator in Addition to Dryer ($/yr)				
Maintenance @ 5%	21,300	34,000	21,300	34,000
Labor	18,000	18,000	18,000	18,000
Property Tax and Insurance	9,500	15,300	9,500	15,300
Evaporator Fuel (Nat. Gas)	43,800	-	175,200	-
Evaporator Steam		28,600		78,900
Additional Fuel to Dry Concentrate and Screenings/Cake	25,200	25,200	100,800	100,800
R.O.I., % (Assuming 15 Yr. Life with No Salvage Value)	15.09	8.02	No return on investment	No return on investment

A SYSTEMS APPROACH TO EFFLUENT ABATEMENT BY HAWAII'S SUGAR CANE INDUSTRY

by

Wm. Kenda* and Q. Dick Stephen-Hassard*

INTRODUCTION

Lush green sugar cane fields contrasted with soiled Pacific waters, have for 25 years, been a spectacle witnessed by most all travelers to and from the Big Island of Hawaii. At the root of the problem on the one hand is a condition of exceedingly wet weather, some 12 feet of rain per year (not inches); and on the other mechanical harvesting and cane processing practices which provide no other economical alternative for waste discharge than the ocean. Though the sugar industry has been developing in Hawaii for over 100 years serious water pollution problems did not develop until the advent of mechanical harvesting in the late forties. Mechanical harvesting's debut was largely brought about by labor shortages following World War II. Figure 1A is a very generalized representation of the sugar industry contributions to the island ecosystem.

The island of Hawaii is a high island of volcanic origin, the precipitious north coast being the site of the majority of cane culture. Without exception mills along this coast are located near high cliffs close to the ocean. There is a historical reason for this in that prior to mechanical harvesting hand cut cane was flumed down to these mills. Such hand cut cane (Figure 2) was free of leaf trash and rarely was exposed to soil. Nowadays labor costs (some 400 men were required in the field) and probably even the discharge of flume water preclude the return of this clean method of harvesting cane. Thus ongoing pollution abatement is directed towards improved mechanical harvesting, materials handling and cane cleaning plant operation. The basic philosophy is to prevent soil to cane contact in the field during harvesting and transporting, and eliminate soil to water contact at the cane cleaning plant.

Brief mention of existing harvesting, handling and cleaning methods is necessary to understand the magnitude of the abatement problem. Twenty-four to thirty-six month old cane averaging around 100 tons per acre is harvested by specialized dozers employing V-cutting blades or push rake attachments (Figures 3, 4, 5). Such vehicles respectively cut or snap off the cane at the stool and windrow the cane. The windrowed cane is then either placed in a tracked buggy (Figure 6) by a crane or picked up directly by a pickup transport (not shown) and brought to roadside and dumped on the ground. From here it is loaded by crane (Figures 6, 7, 8) into trucks for transport to the mill. It should be noted that the cane harvested on this coast is usually heavily laden with leaf trash because

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*President, Hilo Coast Processing Company, Pepeekeo, Hawaii

*Environmental Protection Coordinator, C. Brewer and Company, Limited, Hilo, Hawaii

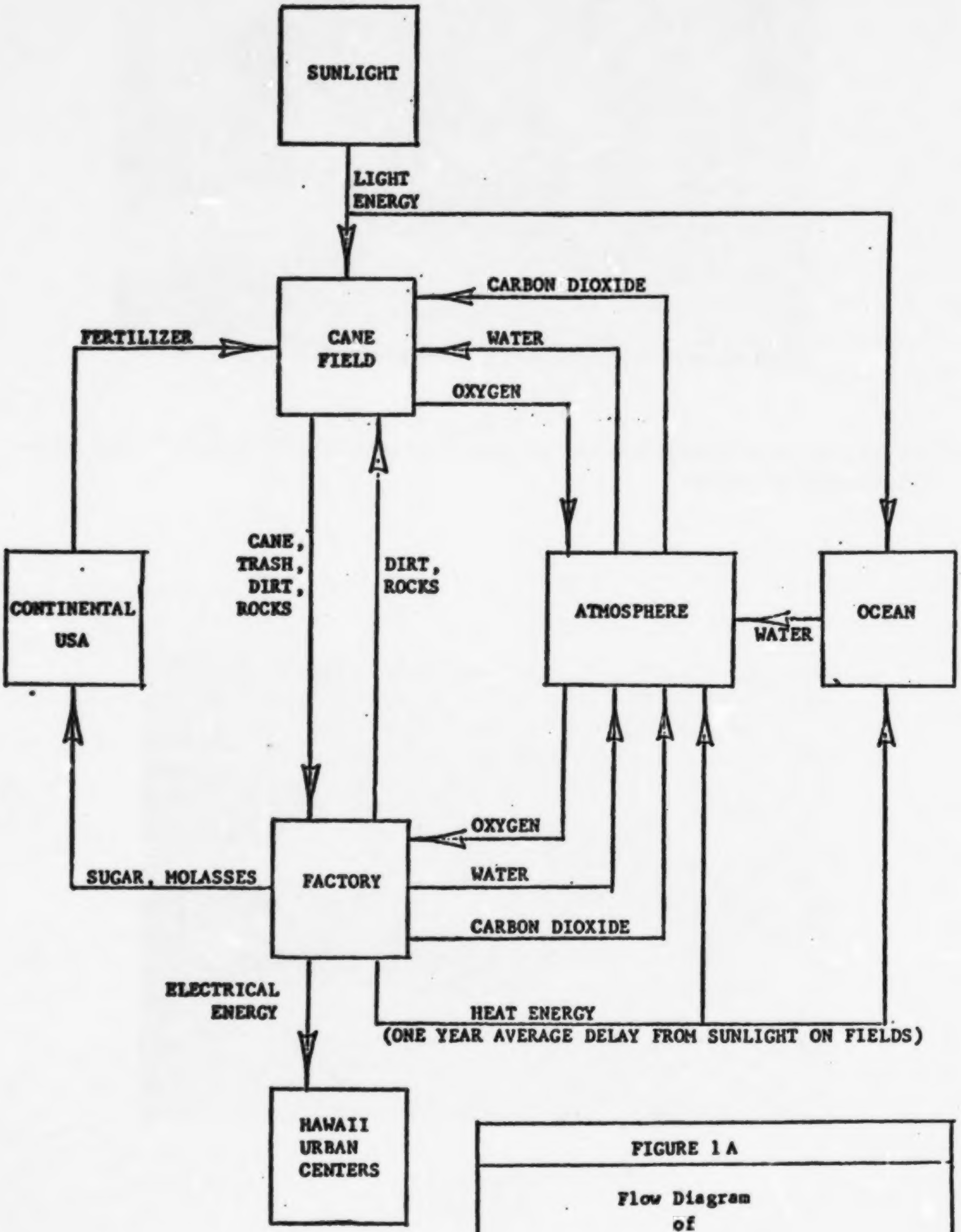

SUNLIGHT
LIGHT ENERGY
CARBON DIOXIDE
FERTILIZER
CANE FIELD
WATER
OXYGEN
CANE, TRASH, DIRT, ROCKS
DIRT, ROCKS
CONTINENTAL USA
ATMOSPHERE
WATER
OCEAN
OXYGEN
SUGAR, MOLASSES
FACTORY
WATER
CARBON DIOXIDE
ELECTRICAL ENERGY
HEAT ENERGY
(ONE YEAR AVERAGE DELAY FROM SUNLIGHT ON FIELDS)
HAWAII URBAN CENTERS

FIGURE 1 A

Flow Diagram
of
Energy and Materials

Figure 2
Shows the traditional method of cane harvesting used prior to the advent of mechanical means.

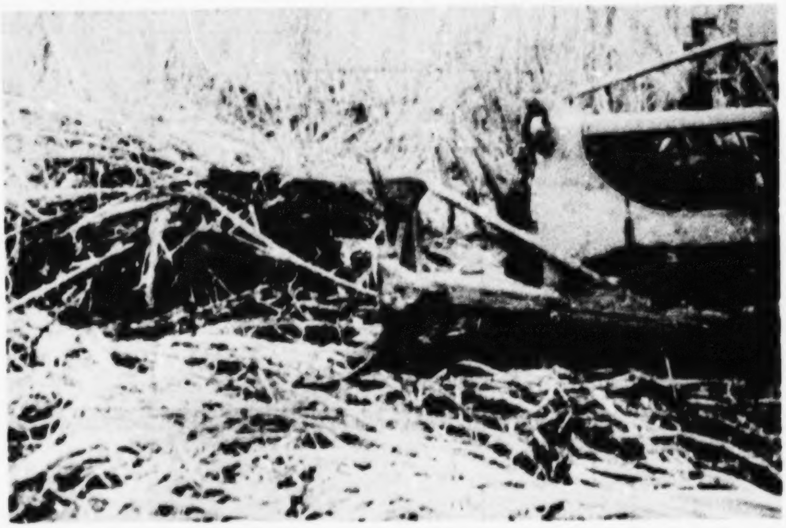


Figure 3
Pushrake

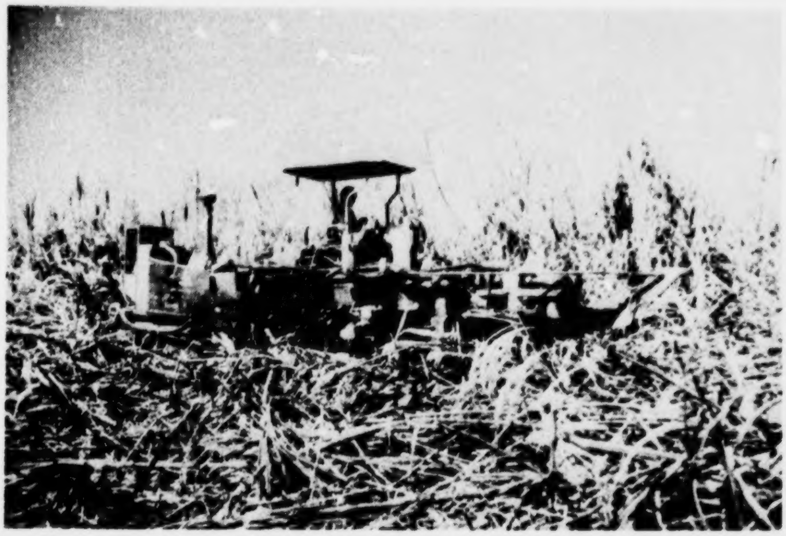


Figure 4
V-Cutter

Figure 5
Conventional V-Cutter
Standard cutting wheels in front are to separate cane. Cutting is done by lead edge of "Vee."

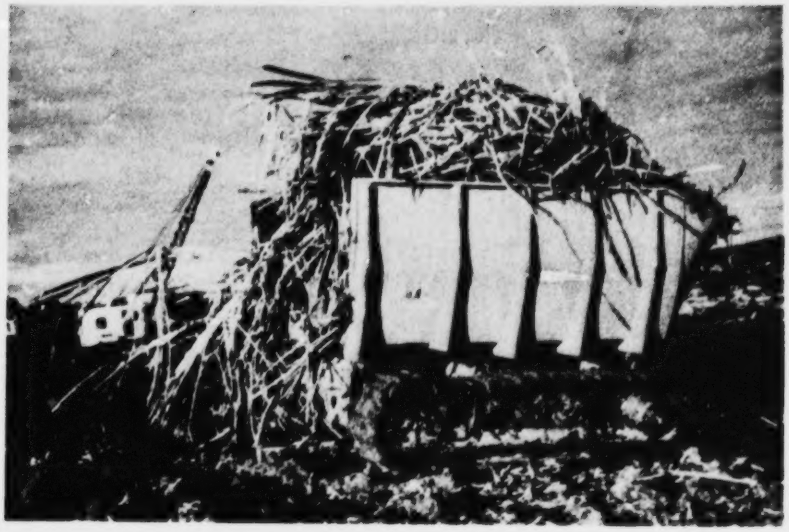


Figure 6
Buggy with Crane (loader) background

Figure 7
Hilo Coast Cane Truck
Loaded trucks gross from 40 to 60 tons

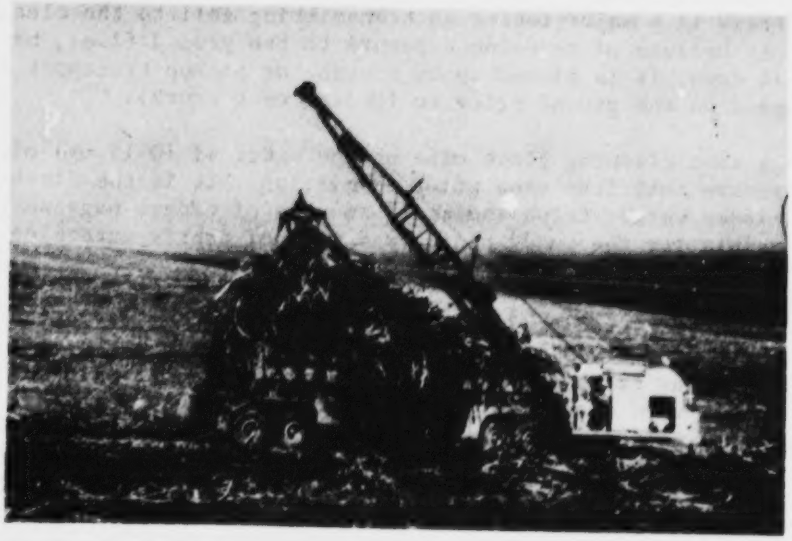


Figure 8
Present method of roadside loading

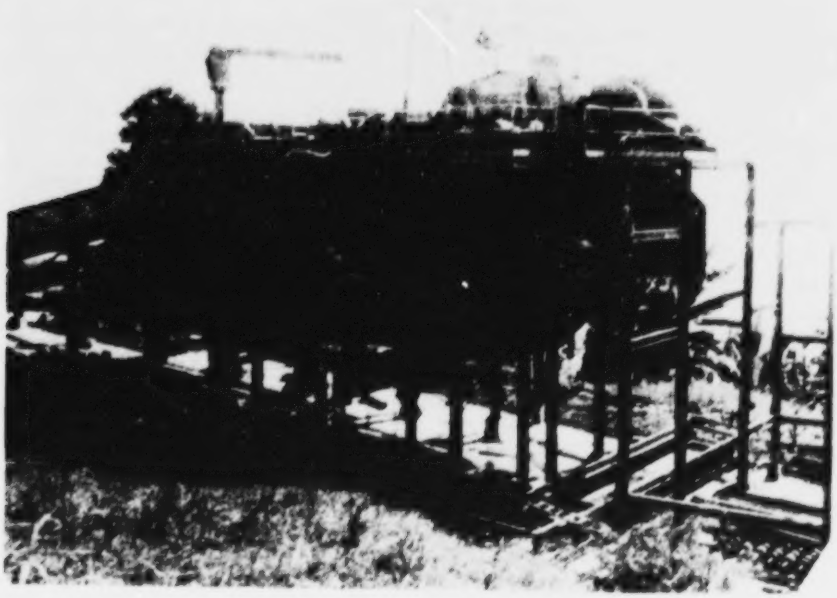


Figure 9
Dry Cleaner Pilot Plant
Basic Unit relocated at Papaikou. Framework was started for additional components before strike. Note new soil removal rolls stockpiled at lower right.

cane burns are not usually effective due again to wet weather conditions. The leaf trash is a major factor in transmitting soil to the cleaning plant mainly because of repeated exposure to the ground (i.e., harvesting cuts it down, it is picked up by a crane or pickup transport and again dropped on the ground prior to loading on a truck).

The average cane cleaning plant uses on the order of 10-15 mgd of fresh water to remove soil from cane prior to milling. It is the discharge of this soil laden water, trash and small amounts of excess bagasse which are responsible for the muddy plumes and mats of debris extending off shore from the mills.

Our approach to the problem is modification of existing harvesting systems to chop and dry clean cane (using forced draft fans) in the field leaving behind the trash and much of the soil. This is followed by direct deposition of cane from the pickup cleaner in a truck for transport to the mill effectively eliminating repeated ground contact. In this phase alone according to recent tests the percentage of trash and soil is shown to be reduced from 45% to 15%. The results also indicate a possible increase in sugar recovery of about 5%; however, it is just at the time of this meeting that we are reaching a position in our development and construction work to verify this important aspect of our work.

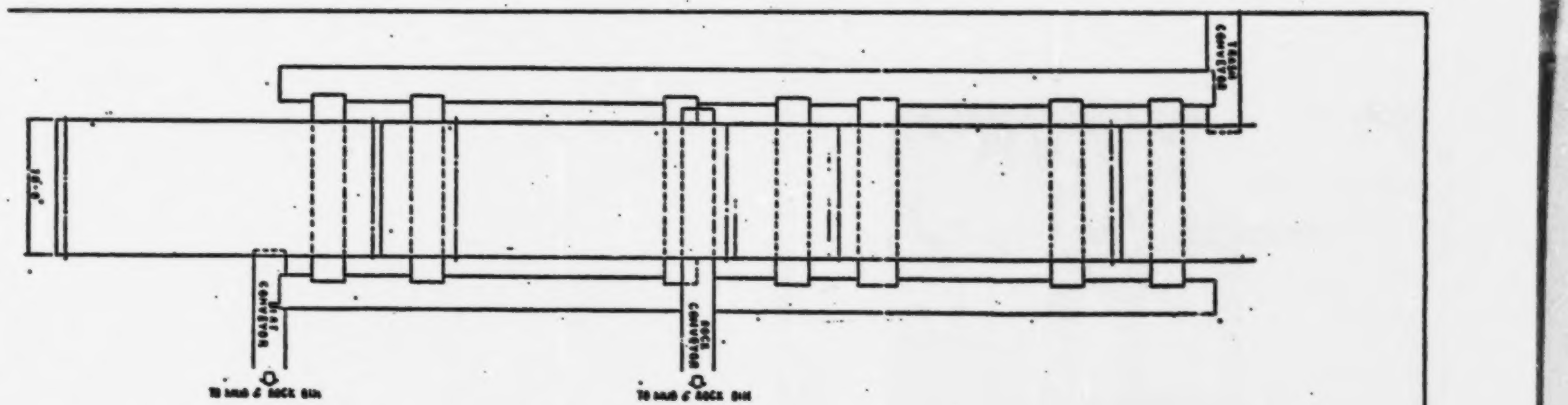
The pilot cleaning plant consists of a dry cleaner and a juice washing system (Figures 9 & 10). Preliminary results of the dry cleaning plant alone show a potential increase in sugar recovery of up to 5%. Data on the juice bath and final version of the pilot dry cleaner are not yet available because of a five-month strike delay which prevented completion of the units. (It was believed at the time the abstract was submitted dry cleaner and juice bath tests would be available--because of the strike delay they are not and this paper is necessarily incomplete.)

Harvester and materials handling development is being carried out on Mauna Kea Sugar Company fields while the dry cleaner and juice washing projects are being developed at Papaikou Mill. Water treatment work is being carried out at the Pepeekeo Mill.

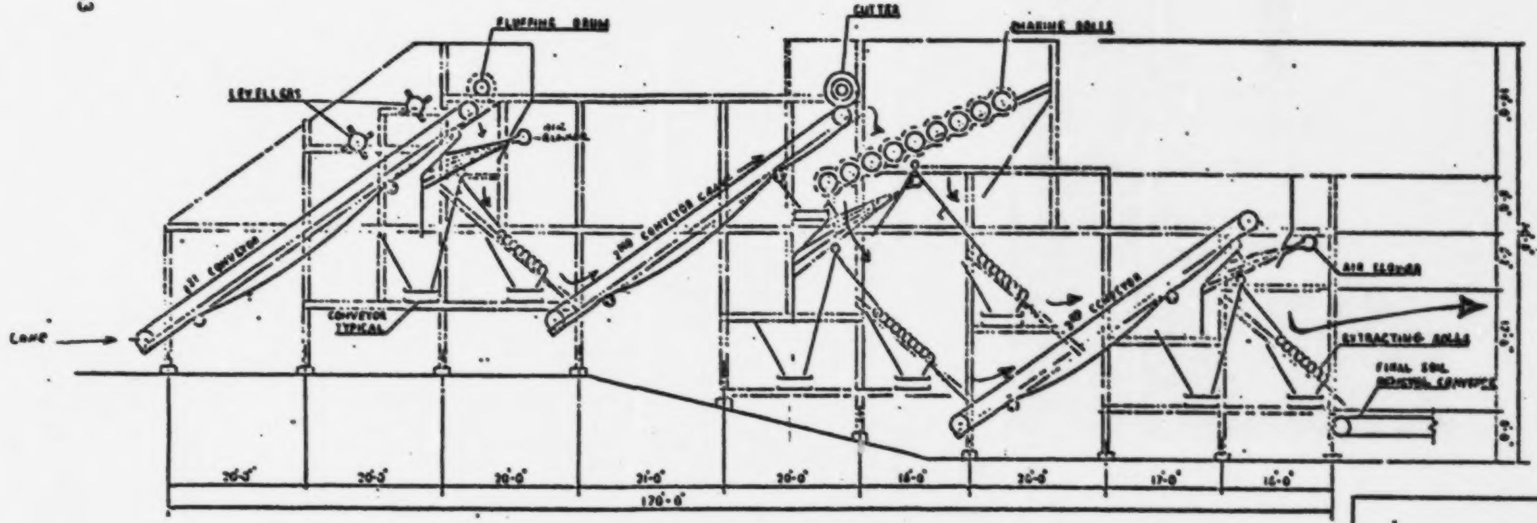
Figure 1B gives an overview of factory locations throughout the State. Papaikou and Pepeekeo are underlined. The majority of plantations listed are irrigated which provides a feasible means of disposal by returning waste to the fields in irrigation water. Fibrous waste is also less at these plantations because of the dry climate allowing greater trash reduction through cane fires.

METHODS AND RESULTS

The uniqueness of the approach to solving the discharge problems on the Hilo-Hamakua coast lies in a synthesis from largely existing harvesting, transporting, cane cleaning and disposal technology. Seven systems summarized in Figure 11 comprise the abatement plan and each is individually discussed below including progress to date.


TRASH CONVEYOR
16'-0"
MAT CONVEYOR
TO MUD & ROCK BIN
ROCK CONVEYOR
TO MUD & ROCK BIN

PLAN VIEW


FLUFFING DRUM
LEVELLERS
AIR BLOWER
CUTTER
SHAKING ROLLS
CANE
1ST CONVEYOR
CONVEYOR TYPICAL
2ND CONVEYOR CANE
3RD CONVEYOR
AIR BLOWER
EXTRACTING ROLLS
FINAL SOIL REMOVAL CONVEYOR
16'-0"
8'-0"
6'-0"
17'-0"
6'-0"
46'-0"
20'-0"
20'-0"
20'-0"
21'-0"
20'-0"
16'-0"
20'-0"
17'-0"
16'-0"
170'-0"

SIDE ELEVATION

Figure 9A

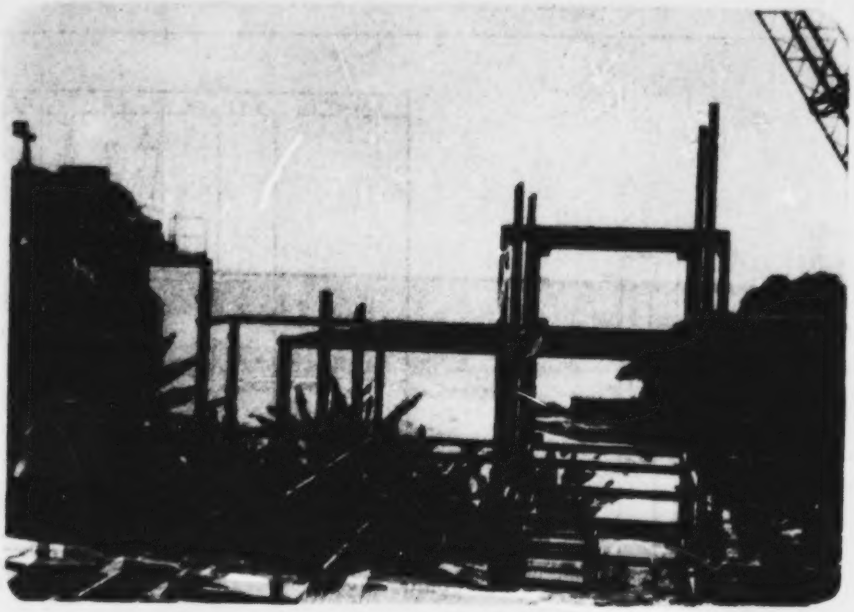


Figure 10

Dry Cleaner Pilot Plant

Framework for soil removers and at far right, framework for second trash blower and Juice Wet Cleaner.

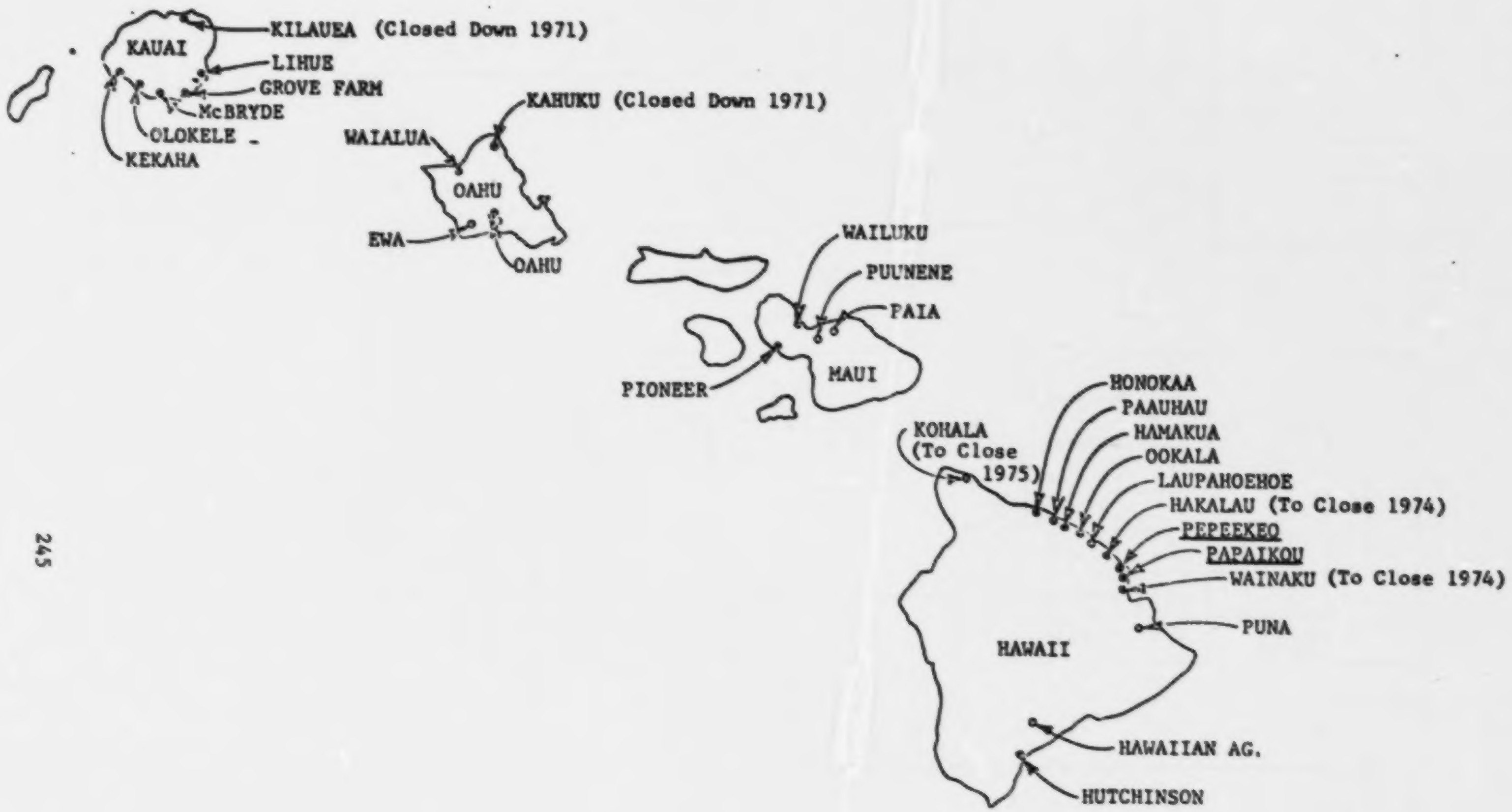

KAUAI
KILAUEA (Closed Down 1971)
LIHUE
GROVE FARM
McBRYDE
OLOKELE
KEKAHA
KAHUKU (Closed Down 1971)
WAIALUA
OAHU
EWA
OAHU
WAILUKU
PUUNENE
PAIA
PIONEER
MAUI
KOHALA (To Close 1975)
HONOKAA
PAAUHAU
HAMAKUA
OOKALA
LAUPAHOEHOE
HAKALAU (To Close 1974)
PEPEEKEO
PAPAIKOU
WAINAKU (To Close 1974)
PUNA
HAWAII
HAWAIIAN AG.
HUTCHINSON

Figure 1B
SUGAR MILL SITES IN HAWAII

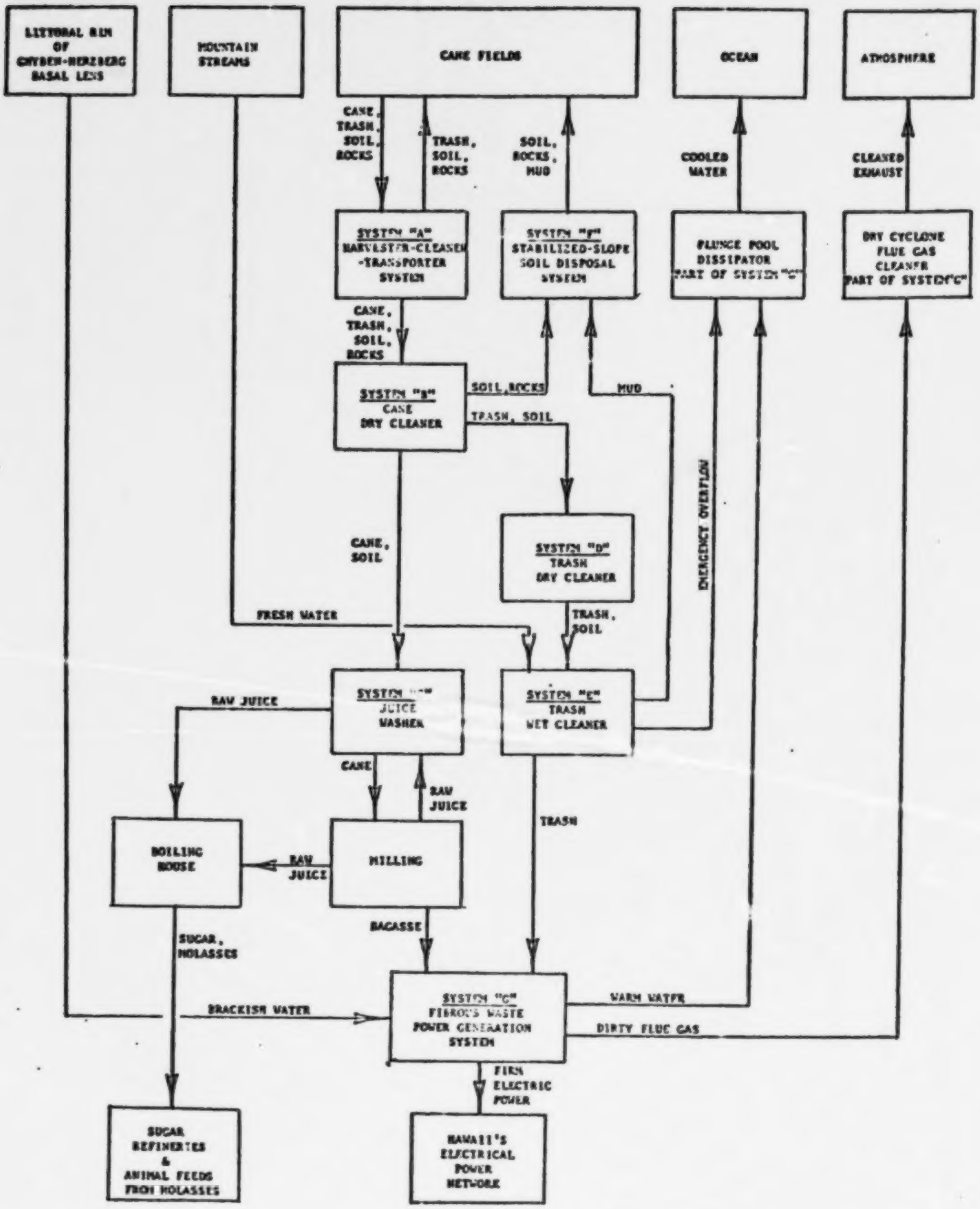

LITTORAL RIM OF GHYBEN-HERZBERG BASAL LENS
MOUNTAIN STREAMS
CANE FIELDS
OCEAN
ATMOSPHERE
CANE, TRASH, SOIL, ROCKS
TRASH, SOIL, ROCKS
SOIL, ROCKS, MUD
COOLED WATER
CLEANED EXHAUST
SYSTEM "A" HARVESTER-CLEANER-TRANSPORTER SYSTEM
SYSTEM "F" STABILIZED-SLOPE SOIL DISPOSAL SYSTEM
PLUNGE POOL DISSIPATOR PART OF SYSTEM "G"
DRY CYCLONE FLUE GAS CLEANER PART OF SYSTEM "G"
CANE, TRASH, SOIL, ROCKS
SYSTEM "B" CANE DRY CLEANER
SOIL, ROCKS
MUD
TRASH, SOIL
EMERGENCY OVERFLOW
CANE, SOIL
SYSTEM "D" TRASH DRY CLEANER
FRESH WATER
TRASH, SOIL
RAW JUICE
SYSTEM "C" JUICE WASHER
SYSTEM "E" TRASH WET CLEANER
CANE
RAW JUICE
TRASH
BOILING HOUSE
RAW JUICE
MILLING
SUGAR, MOLASSES
BAGASSE
BRACKISH WATER
SYSTEM "G" FIBROUS WASTE POWER GENERATION SYSTEM
WARM WATER
DIRTY FLUE GAS
FIRM ELECTRIC POWER
SUGAR REFINERIES & ANIMAL FEEDS FROM MOLASSES
HAWAII'S ELECTRICAL POWER NETWORK

FIGURE 11

PROTOTYPE COMPONENT SYSTEMS

ECOSTATIC CANE PROCESSING SYSTEM

SYSTEM A - PILOT HARVESTER CLEANER SYSTEM

Improved V-Cutter:

Tests over the past 20 years have shown that some form of the present V-Cutter will continue to be necessary to cut the long recumbent cane on the steep, wet slopes of the Hilo coast. Initially improvements were planned to enable V-cutters to cut cane rows in one pass rather than the two now required, thereby reducing the mangling together of cane, soil and rocks. Two approaches were used:

1. Rapid sharpening and quick replacement of conventional cutting edges.

2. Use of rotary blades.

Neither system was successful. Methods used for frequent sharpening and replacement of blades were too expensive in terms of labor and down time. The rotary blade machine encountered severe "gouging" problems. If the blades were set low enough to sever the recumbent cane just above the stools (roots), they commonly dug in and tore out stools and damaged themselves on rocks. If the blades were set too high the stalks remained attached to the stools.

For the time being the existing method of V-cutting (Figure 5) will be employed. After full development of the Prototype Pickup Cleaner and roadside handling is further improved the attack on V-cutter problems will resume.

Pickup Cleaner:

The objective of the Pickup Cleaner (Figure 12) is to economically:

1. Pickup cane windrowed by V-Cutters and cane grabs.

2. Remove the major portion of dirt and leaf trash and return them directly to the field.

3. Transport the cane stalks to the roadside for direct transfer to trucks.

All objectives have been met for the Pilot Model.

A two-bladed Australian chopper was redesigned for 3 blades (Figure 13), greatly improving throughput and quality of cane. A rock gap followed by a high speed slat conveyor over narrow parallel bars provides a high degree of rock and soil removal. After numerous redesigns the extractor fans (Figure 14) successfully remove additional soil and separate the leaf trash from the stalks. The detrashed stalks, about eighteen inches in length are contained in a transfer box until off loading to an infield transport unit. The Prototype resulting from this Pilot Model incorporates an elevator type unloader rather than an ejector for direct loading trucks.

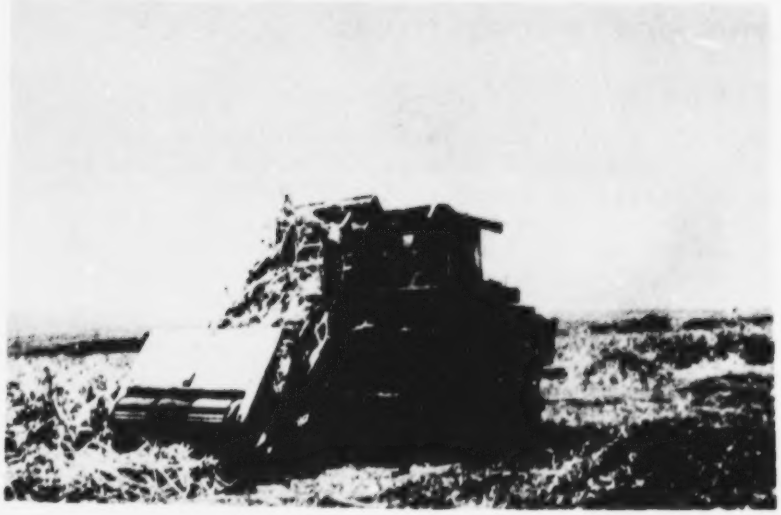


Figure 12
Pickup Cleaner

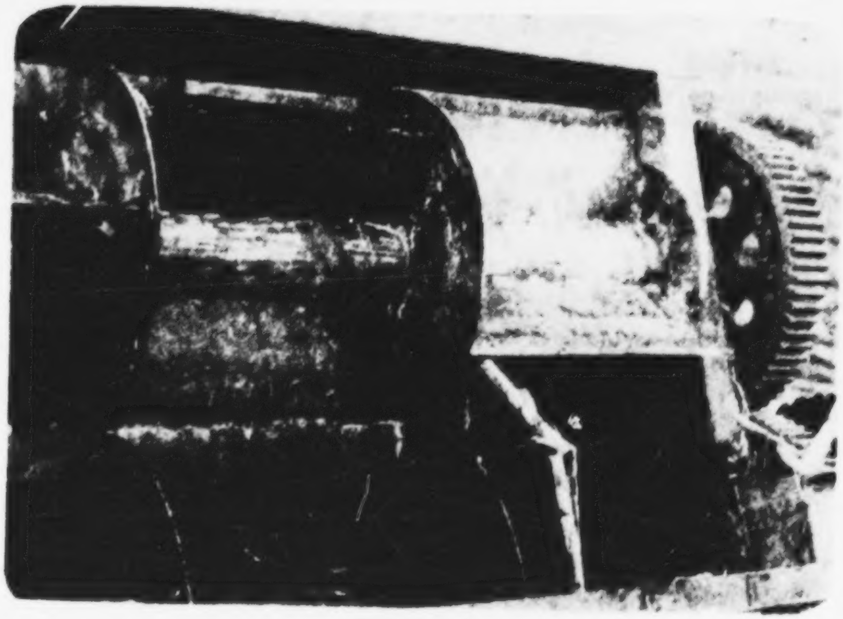


Figure 13
Pickup Cleaner - Pilot Model
Choppers modified from two cutting edges to three at significant increase in quality and quantity. Note pincher action.

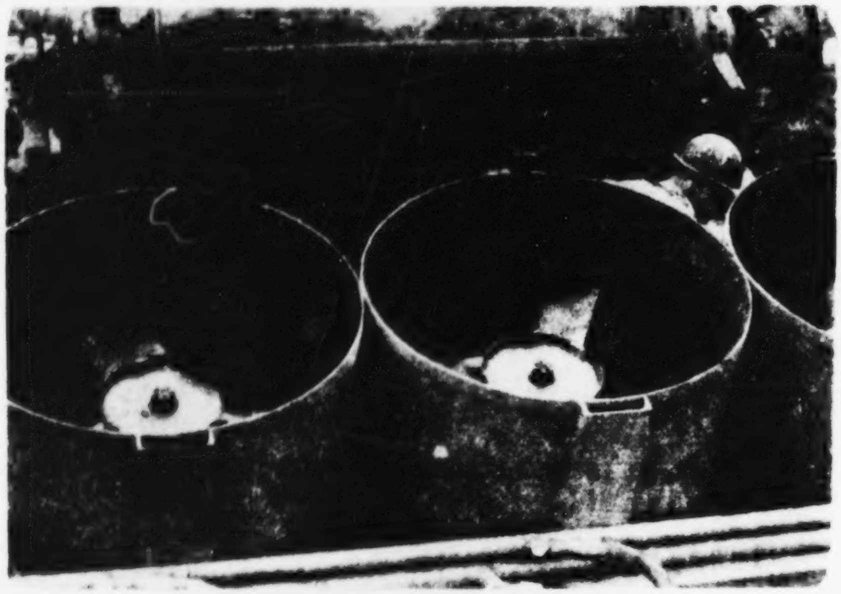


Figure 14

Pickup Cleaner - Pilot Model

Extractor fans separate trash (cane tops and leaves) from cane stalks. Fans, mounts and cowls underwent many modifications before satisfactory operation was obtained.

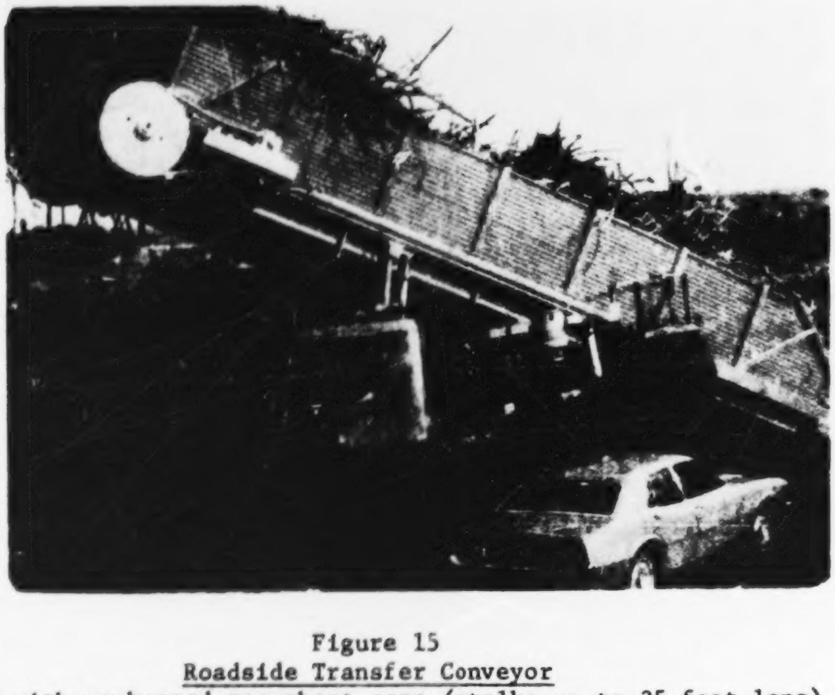


Figure 15

Roadside Transfer Conveyor

Test load with unchopped recumbent cane (stalks up to 35 feet long). Conveyor lacks lateral mobility. Prototype will be changed to rotate up to 90° with trades.

Side slope operation caused bunching of the cane under one of the three extractor fans. The Prototype Pickup Cleaner has incorporated a self-leveling mechanism for all of the body except the pickup head. The Pickup Cleaner results to date are illustrated below:

	Gross Field Cane	Net Cane	Remaining Trash & Stools	Soil Remaining
Old System	100%	55%	28%	17%
Harvester-Cleaner System	100%	85%	11%	4%

Roadside Transfer Conveyor (Figure 15)

This pilot model readily fulfilled its purpose of accepting and lifting cane stalks into waiting trucks, thereby eliminating the soil adhering to the cane through the roadside cane grab operation (Figure 5). However, positioning the cane trucks and the Roadside Transfer Conveyor took too much time. A prototype modified buggy which can store cane received from the pickup cleaner then transfer it into a truck at roadside is to be constructed shortly.

Portable Harvest Road (Figure 16)

Permanent in-field roads on the Hilo Coast are expensive; they remove land from productive use, result in increased soil erosion, and are used only 10 days every two years. The Hilo Coast cane hauling road system totals 515 miles at the present time. Recent studies showed that efficiency of harvest operations could be greatly improved and soil contamination of remnant cane ("liliko cane") could be greatly reduced by placing a harvest road down the middle of each field. A fiberglass temporary road currently in use by the Army appeared a promising solution. Under field testing the fiberglass road was significantly damaged after only 12 hours use by cane trucks (Figure 7). The high cost of this material ($2/sq. ft.) requires a useful life two orders of magnitude greater to warrant its use as a field road.

SYSTEM B - CANE DRY CLEANER PLANT (Figures 9 & 10)

The traditional approach to removing waste from waste water is to treat the waste water. In the Cane Dry Cleaner concept a large proportion of the soil and waste material remaining after harvest are removed before any washing. The Pilot plant consists of the following:

Gathering Conveyor:

Accepts the transfer of cane stalks and trash (cane tops and leaves) from the cane hauler truck units and moves this material to the Leveling and Carding units.

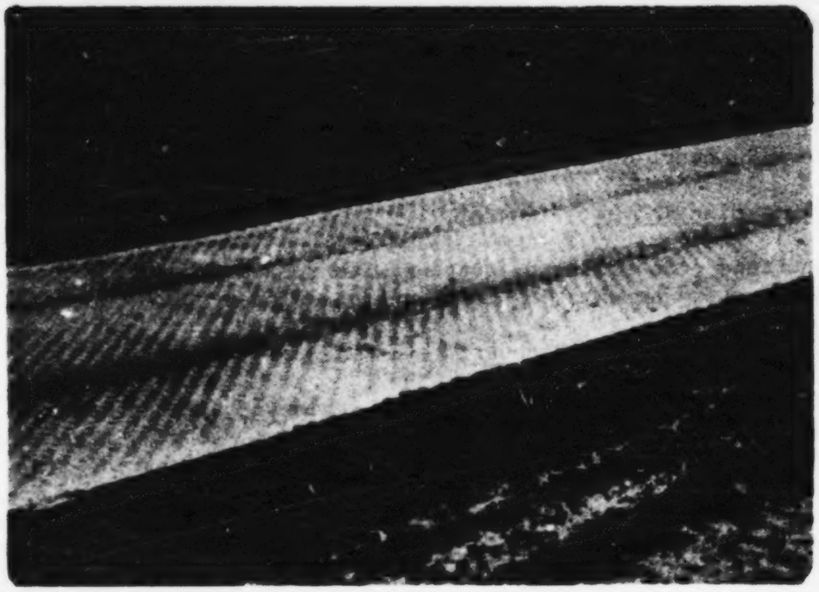


Figure 16
Portable Harvest Road
Fiberglass Test road in place.

Leveling and Carding Units:

Levels and cards cane, thereby distributing a thin mat of cane on the first elevating carrier. The establishment of a thin mat of cane is essential to successful subsequent operations of the Rock Remover, Soil Remover, and Trash-Cane Separator.

Shortening Knives:

Shortens cane stalks by cutting with rotating knives preparatory to entering further processing steps.

Shaking Drums/Rock Remover:

Shortened cane stalks drop onto a series of shaking drums. Drums are spiked with a multitude of tines set at a raked angle. The tines will impact against the cane stalks, shaking off loosely adhering dirt and leaves. From development work done elsewhere, it is believed that these same tines, set at the proper angle, will cause rocks to work themselves counter to the general flow of cane and eventually drop off at the back (low) end of the shaking drums. Rocks discharging here will be conveyed away by a separate conveyor.

Primary and Secondary Trash-Cane Separators:

Separates the trash and soil from cane by air blasts.

Soil Remover:

Removes additional soil in the dry state by separating action produced by a system of special collar rolls.

To increase its soil removal capabilities a set of these special collar rolls will be inserted immediately below the counterflow conveyor on the basic unit's trash-cane separator (for detail see Sheet M-9-3 Reference 10) and a second blower for trash-cane separation will be added just prior to the Juice Wet Cleaner Rolls.

Emergency Cane Stalk Bath:

Washes off mud on the cane stalks if unusually muddy field conditions prohibit continuance of cane dry cleaning. This Emergency Bath must be used as little as possible because of high sugar losses to be expected from wet cleaning the cane that has been torn in the dry cleaner carding units and shaking drums.

Evaluation of the cleaning capability of the dry cleaner will be made at process control points using the methods described in Reference 7.

Both the sucrose levels and quantities of soil material in dry cleaned cane will be studied to determine the most efficient configuration of the dry cleaner. Evaluation of economic implications will be made by standard industrial engineering evaluative techniques.

SYSTEM C - JUICE WASHER

The objective is to develop a Juice Washer plant that will utilize cane juice to wash off any remaining dirt clinging to the cane stalks after they pass through the Dry Cleaner Plant Soil Remover, and which will economically clean the cane juice without allowing juice deterioration. As explained elsewhere, the dry cleaner cannot be made to operate without this juice washer system.

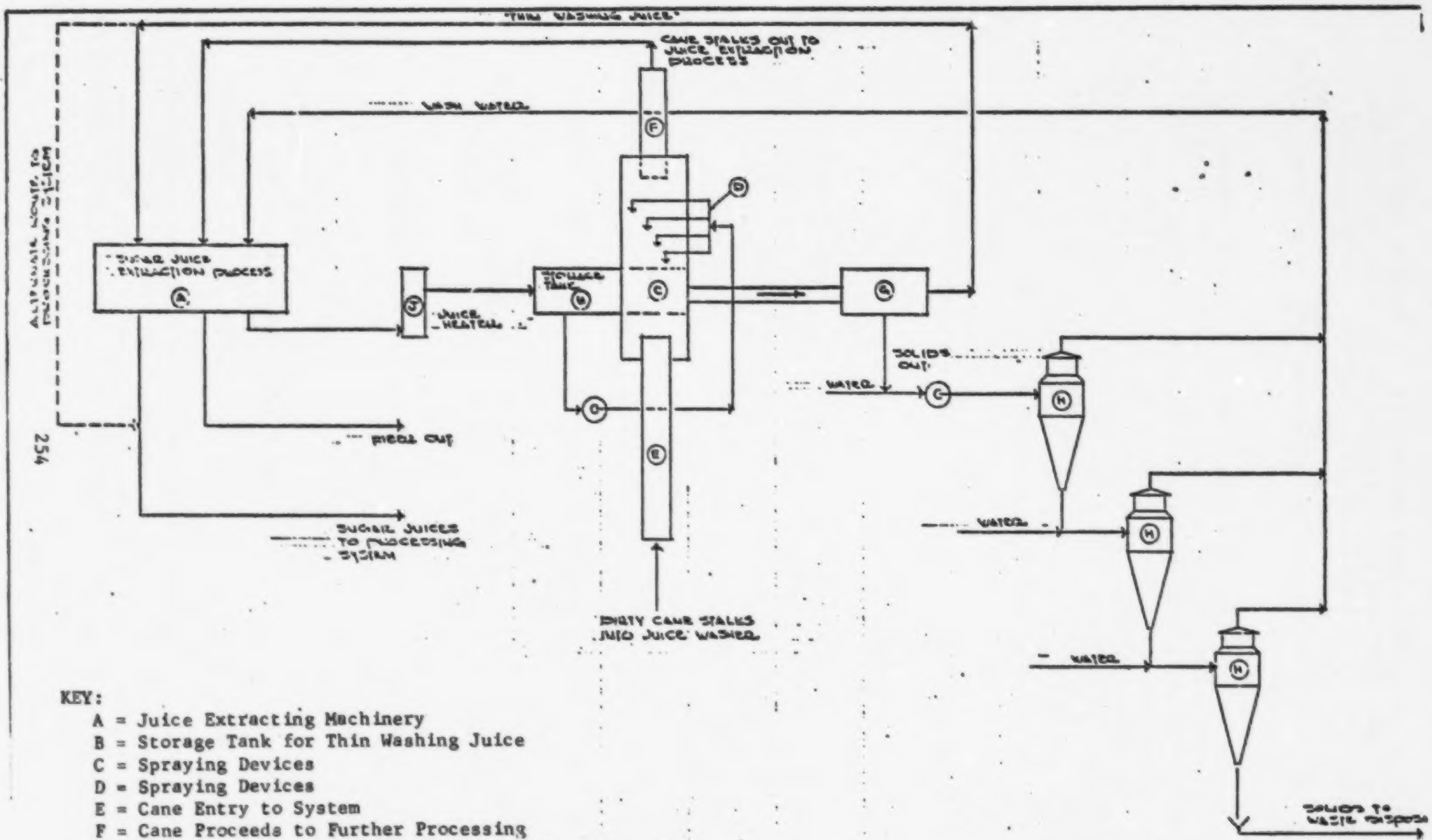
The major purposes are to eliminate sugar loss in the cane cleaner and subsequent pollution caused by wet washing with water. Additional soil in the juice will increase filter station losses in the process house; however, we feel the loss will be substantially less than that encountered in wet washing with water in the cane cleaner. Past experience with the first Dry Cleaner test plant indicates that maintaining a thin mat of cane is absolutely essential to successful dry cleaner operation. The difficulty is that a thin mat can only be attained by means that bruise and tear the cane to the extent that wet cleaning will result in very high sugar leaching transfer to the wash water. Thus the Juice Washer is an absolutely essential adjunct to a successful dry cleaner. The Juice Washer Pilot Plant at Papaikou Mill is to consist of (Figure 17):

> Cane Stalk Juice Bath:
>
> Its purpose is to clean off mud still clinging to cane stalks by spraying sugar juice extracted by the processing plant mill rolls. The object is to lessen sugar losses (and pollution problems) resulting from sugar leaching out of breaks in the cane stalks.
>
> Grit Separator:
>
> To seperate the grit economically from the dirty juice but without entraining excessive sugar in the waste material.
>
> The Juice Washer Pilot Plant will operate on a mixed cane juice flow of 800 gpm.

Analysis of samples(7) at multiple points along the path traveled by the juice will be critical in determining the efficacy of juice cleaning of cane.

Major losses in recovery can occur if the juice is retarded in any way or the other two variables are not carefully controlled.

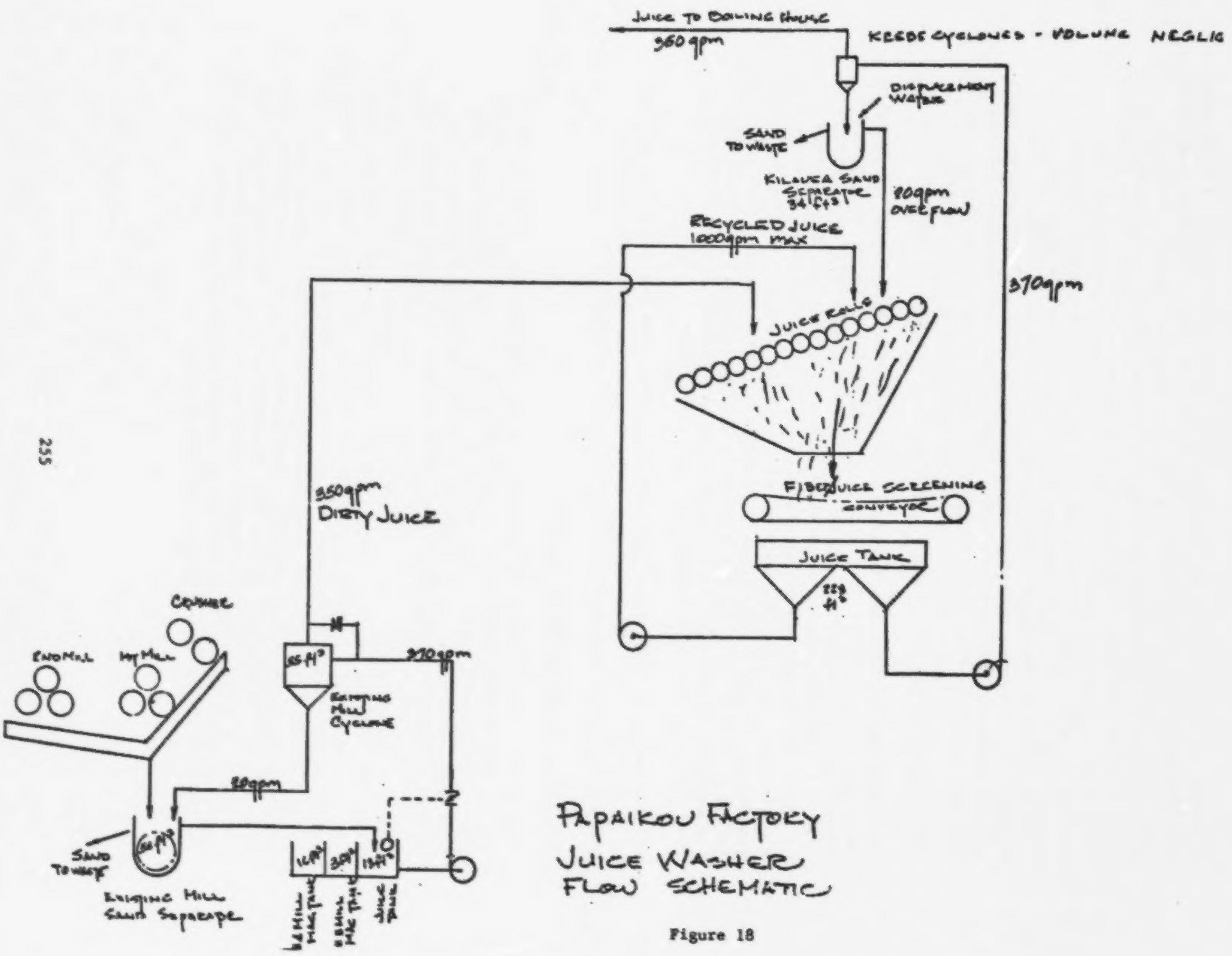
The original juice washing arrangement of R. T. Webb(9) has been considerably modified in the past few months. Figure 18 is a schematic drawing of the present design. Three major problems arose in the original system: 1) High maintenance costs of the liquid cyclones; 2) Excessive fluid build-up due to numerous dilutions; 3) Inversion of sugars due to excessive retention times. Extensive small scale tests have been completed. Although the researchers are cautiously optimistic, it is not yet known with certainty if problems with sucrose inversion and bacterial contamination can be avoided. No full scale tests have been possible because of interruption of fabrication by striking iron workers.


"THIN WASHING JUICE"
CANE STALKS OUT TO JUICE EXTRACTION PROCESS
WASH WATER
ALTERNATE ROUTE TO PROCESSING SYSTEM
SUGAR JUICE EXTRACTION PROCESS
A
J
JUICE HEATER
STORAGE TANK
B
C
D
E
F
G
H
FIBER OUT
SUGAR JUICES TO PROCESSING SYSTEM
DIRTY CANE STALKS INTO JUICE WASHER
SOLIDS OUT
WATER
WATER
WATER
SOLIDS TO WASTE DISPOSAL

KEY:
A = Juice Extracting Machinery
B = Storage Tank for Thin Washing Juice
C = Spraying Devices
D = Spraying Devices
E = Cane Entry to System
F = Cane Proceeds to Further Processing
G = Removal from Thin Washing Juice of Grit, Mud, etc.
H = Insolubie Solids Obtained in "G" Are Washed With Water
J = Juice Heater 170°F.

Flow Diagram
Juice Cane Washing

Figure 17



JUICE TO BOILING HOUSE
360 gpm
KEEBS CYCLONES - VOLUME NEGLIG
DISPLACEMENT WATER
SAND TO WASTE
KILAUEA SAND SEPARATOR 34 ft³
80 gpm OVERFLOW
RECYCLED JUICE 1000 gpm MAX
370 gpm
JUICE ROLLS
FIBER/JUICE SCREENING CONVEYOR
JUICE TANK
222 ft³
350 gpm DIRTY JUICE
CRUSHER
END MILL
1st MILL
55 ft³
EXISTING MILL CYCLONE
370 gpm
80 gpm
SAND TO WASTE
64 ft³
EXISTING MILL SAND SEPARATOR
16 ft³
3 ft³
13 ft³
#4 MILL MAC TANK
#8 MILL MAC TANK
JUICE TANK

PAPAIKOU FACTORY
JUICE WASHER
FLOW SCHEMATIC

Figure 18

SYSTEM D - TRASH DRY CLEANER

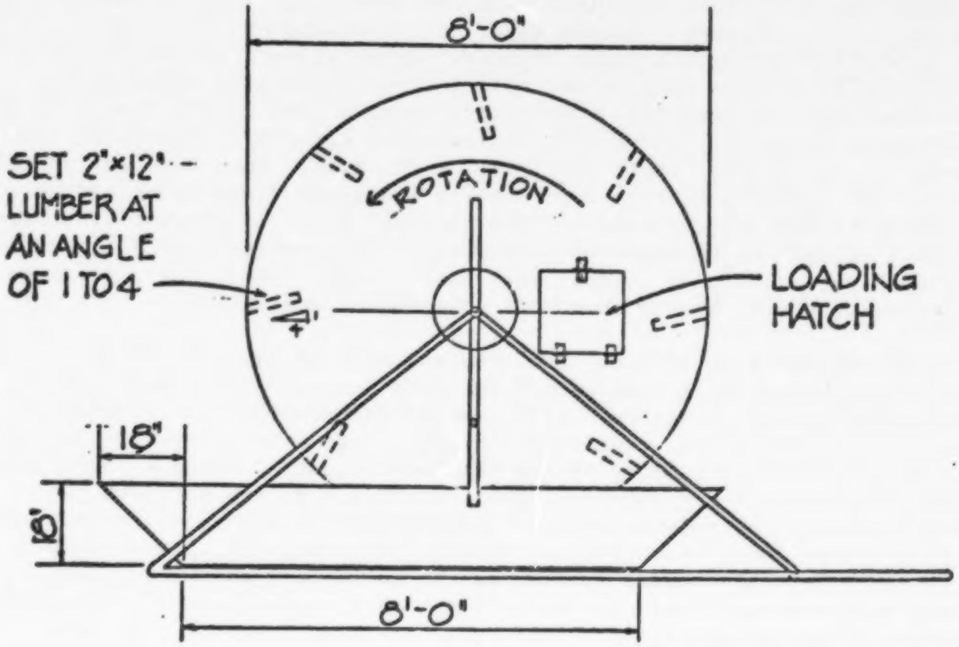
In order to use the waste trash for fuel for electrical power generation, adhering soil must be removed to prevent boiler tube scour and significant lowering of the fuel value of trash. Once the Harvester-Cleaner System and Cane Dry Cleaner Systems are in operation, water to wash this trash will be the most significant waste water source at the affected cane sugar processing plant. To reduce this wastewater further an attempt is being made to dry clean the trash despite major "roping" problems in the past when attempting to handle trash in this manner. Early results of the field test apparatus have been promising. (See Figure 19). Removals under good harvesting conditions were 60% to 80% of that achieved with a water bath. These tests were designed to show the best possible results and should be higher than actual production figures. Tests under muddy harvesting conditions are now in progress. Fabrication of the pilot model has also been delayed by the strike.

The trash dry cleaner as presently conceived will consist of two stages. The first stage will be for the removal of pebbles, rocks, and soil clumps that are separate from the trash. These materials are denser than the trash and can be separated with an air stream. The mixture of trash and extraneous materials will be dropped vertically through a horizontal air stream. Because of the lower density and greater wind resistance of the trash, it will be deflected from its vertical path into the second stage of the cleaner. Optimum separation of the trash and extraneous material is to be achieved by keeping the trash blanket thin and adjusting the velocity of the air stream.

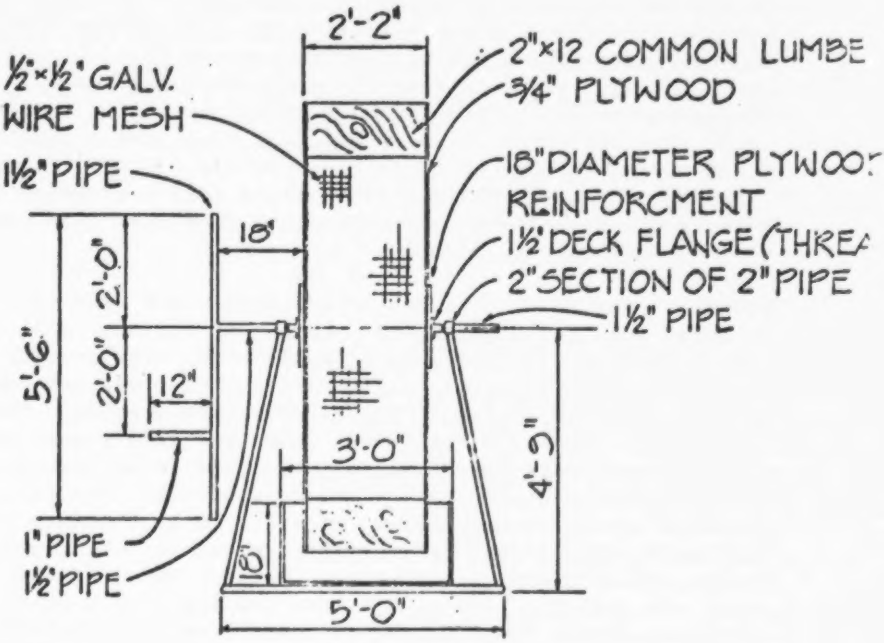
The second stage will be a cylindrical screen. As the cylinder rotates the trash will be lifted almost to the top of the cylinder and fall through its full diameter.

SYSTEM E - WASTE WATER TREATMENT

Treatment of waste water is necessitated by the need for a trash rinse to prevent the detrimental effects of soil on trash combustion properties. Leaf trash will be trucked up the coast from Papaikou Mill for cleaning, dewatering and combustion with Pepeekeo trash hence, water treatment will be centered at the latter plant. Papaikou is expected to have minimal needs for water treatment except during emergency rinse (wet weather) conditions. The future average processing rates of the two mills -- 133 tons net cane per hour for Pepeekeo, and 67 tons net cane per hour at Papaikou -- will provide an average dry soil load of 1000 tons per day under existing harvesting conditions. The new harvesters should remove close to 52% of that though a higher percentage removal may be possible depending upon rainfall. After dry cleaning, to separate cane stalks from trash, part of the soil is carried over into the sugar processing stream by the juice washer which will put an added burden on the juice clarifier. Dry cleaning of the trash should remove another 40% of the dry soil or on the average 153 tons per day.


8'-0"
SET 2"×12"
LUMBER AT
AN ANGLE
OF 1 TO 4
ROTATION
4
1
LOADING
HATCH
18"
18"
8'-0"

PLAN


2'-2"
½"×½" GALV.
WIRE MESH
1½" PIPE
2"×12 COMMON LUMBE
3/4" PLYWOOD
18" DIAMETER PLYWOO
REINFORCMENT
1½" DECK FLANGE (THREA
2" SECTION OF 2" PIPE
1½" PIPE
18"
2'-0"
2'-0"
5'-6"
12"
3'-0"
4'-3"
18
1" PIPE
1½" PIPE
5'-0"

SECTION

Figure 19

Test Apparatus

DRY CLEANER TEST DRUM

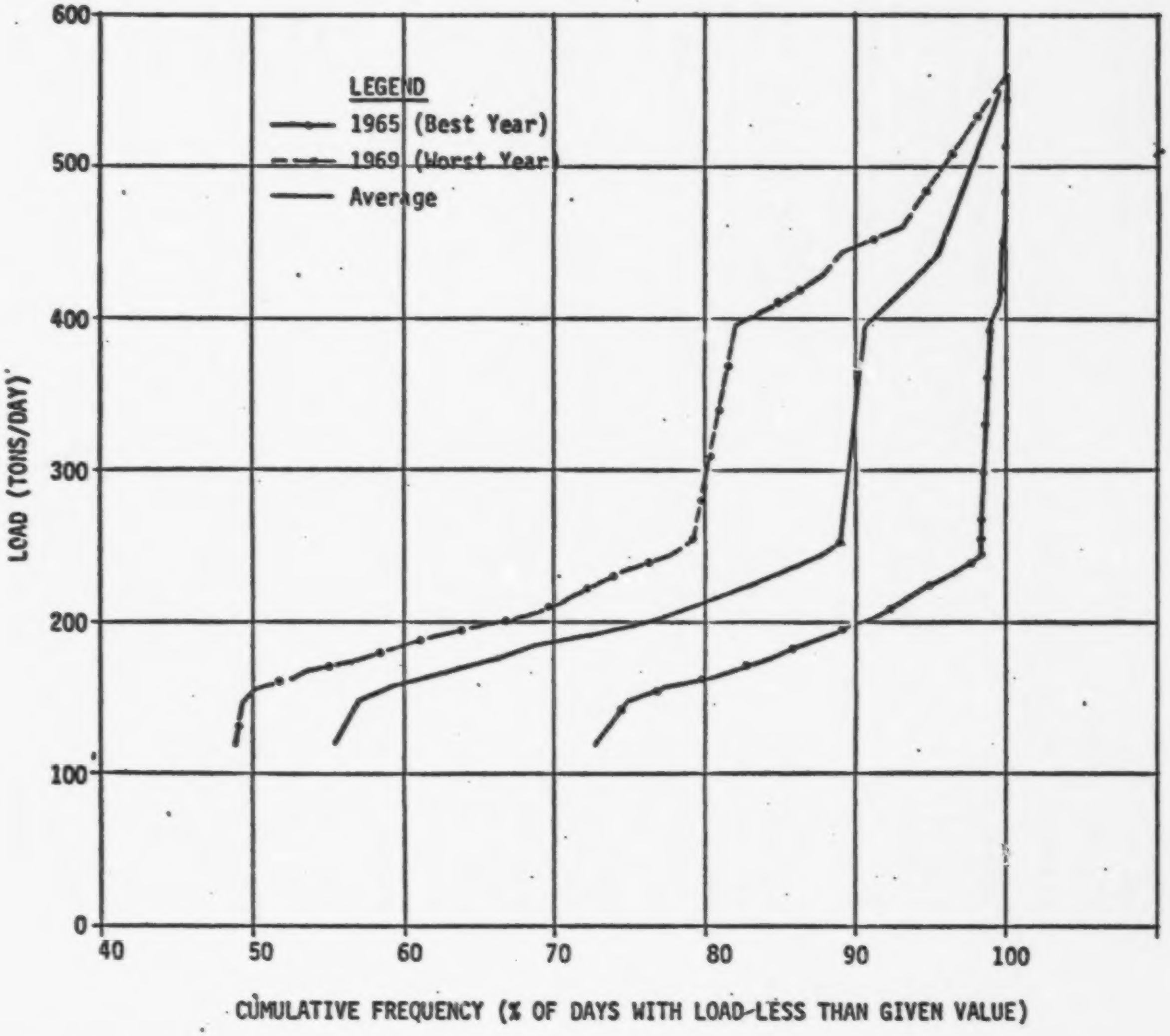
It is estimated that the foregoing systems will remove under normal conditions 85% of the soil load with the remaining 15% to be handled by waste water treatment. Estimates of soil loadings are based upon plantation and Hawaiian Sugar Planters' Association data which show a direct relationship between dry soil intake at the mill and quantity of cane trash (Figure 20). During dry years a load of 250 tons soil per day would occur 98% of the time while during wet years loading of 250 tons per day or less would occur 79% of the time. When such wet periods occur dry cleaning must be augmented by emergency rinse bringing the soil loading to the extreme value of 560 tons per day. It appears that such high loadings can be expected relatively infrequently. Final evaluation of the system designed to deal with such a waste stream and implementation of treatment has to be a cost consequence evaluation.

The consultant firm of Sunn, Low, Tom and Hara of Honolulu which has been developing design parameters for such a system recommends the following general sequence: grit removal polyelectrolyte coagulation and pipe flocculation, clarification and sludge thickening (20-25% water) followed by pumping of the thickened sludge (viscosity 100 times that of water) to dry gulches. Their studies have demonstrated that pipe reactors for polyelectrolyte coagulation and flocculation can replace conventional flocculation chambers and bring substantial cost savings. Initial studies in 1971 by the consultant on the efficacy of tube settlers suggested this to be a suitable approach to clarification. Extensive pilot testing of a tube settler showed however, that this principle is not required for effective clarification with polyelectrolyte treatment. A major component of the waste treatment system developed from these pilot studies is a combined clarifier thickener using polyelectrolyte which will be able to satisfactorily thicken and discharge sludge and also eliminate sludge carry-over. It allows control over extreme variations in waste load during a given day. The relevant design and operating parameters are solids loading (0.1 lb. dry solids/sq. ft./min.), solids residence time (2 hr minimum) and hydraulic overflow rate (1 gpm/sq. ft.)(7). Results of clarification with controlled operating parameters indicated a median effluent suspended solids of 50 mg./L Akaka series solids (particle sizes around 2 micra) reached 200 mg /L. which shows the variability of Hawaiian soil's response to polyelectrolyte treatment. Further thickening of the under flow was shown necessary to keep handling costs down.

At this point in time we cannot adequately evaluate the BOD levels produced when all eight systems become operational and hence, we are not certain of the quantities to be dealt with. The cane dry cleaner and the juice washing systems will, during normal weather conditions, effectively minimize sugar losses which produce BOD. The major source of BOD will come from trash wash water and from squeezings after the trash is dewatered for incineration. This is estimated by Sunn, Low, Tom and Hara to be a total of about 70,000 lbs. per day. Of this quantity it may be possible to divert some 31,000 lbs. per day BOD from the squeezings for use as maceration water or for dilution and/or production of molasses in the process house. This, however, would tend to lower the refining quality of sugar causing costly penalties. If the remaining 39,000 lbs. per day is considered for treatment the resultant suspended solids would be 5,000 mg.L with a mass emission of biomass (Bacteria, Carbon, etc.) of about 10 tons per day. The remaining BOD

FIGURE 20

CUMULATIVE FREQUENCY OF SOIL LOADS
TO WASTEWATER TREATMENT PLANT



level in the pond overflow could vary between 2.5 tons per day and 5 tons per day. This is in contrast with no BOD treatment where 60 mg./L suspended solids would be discharged with, at 5 mgd, would amount to the mass emission of soil of about one ton per day with a median value of 50 JTU turbidity. At times during wet weather and with certain soils the turbidities could run four times the median value giving a discharge of 4 tons per day (similar to natural streams).

EPA data, Grigg (1973)(4), Kennedy Engineers (1967)(5), and other reports, Caswell (1972)(1), Engineering Sciences, Inc. (1971)(2), raise the question of need for expensive BOD treatment and the spectre of transforming an apparently innocuous (in this coastal environmental context) characteristic of discharge into a more serious energy demanding, land disposal problem.

SYSTEM F - STABILIZED SLOPE SOIL DISPOSAL SYSTEM

Solids disposal will be by field spreading with special emphasis on countering the high rainfall. Evaporation rate is much lower than rainfall. Hence, thin layers of thickened sludge over large areas are required to enhance drying during frequent but short periods of sunshine. Pilot tests indicate that once dried, the mud cakes do not disperse despite subsequent wetting.

The high cost of dewatering at the processing plant has made the need imperative for field disposal of liquid sludge. Under these conditions the stabilized slope method utilizing dry materials has given way to the slurry disposal alternative. Current work is concentrated on establishment of ponding criteria. Difficulties are formidable in drying or dewatering the mud in this area of high rainfall.

Spreading of mud slurries is intended for areas which can be reclaimed for cultivation and for fields which need replenishment of top soil. Because of steep slopes, application of soil slurries must be carefully controlled. The high viscosity of thickened sludge significantly impedes its flow on slopes. Diking requirements will be about 1/10 as much for 25% slurries as for those of 10%. Transport of slurry is being designed for pumping with the option of trucking slurry to field sites.

SYSTEM G - STEAM POWER GENERATION FROM FIBROUS WASTE

Generation of electric power from sugar cane waste is not a new idea. For many years the sugar companies on Kauai, Oahu, Maui and Hawaii have generated their own power from bagasse and where possible sold excess power at dump rates to the local utility company. In some cases, for example on Kauai, the sugar companies have had to carry a substantial portion of the load when the utility company had plant failures. What is new about the system at the Pepeekeo plant is a basic change in philosophy from electric power being an adjunct to sugar production to power generation being the primary raison d'etre and sugar production being relegated to a secondary role. The Pepeekeo plant which will produce some 100,000,000 Kilowatt hours of energy annually or 20% of the Connecticut sized island's demand represents a synthesis of features which are unique to the industry. Five major objectives must be achieved to produce an economically viable refuse incinerating power generation facility:

1. Controlled transport of surplus fiber over an appreciable distance, special preparation for high-efficiency burning, and provision for infallibility of supply to boiler.
    - New communication and data processing system being considered to control transportation.
    - Special cleaning and dewatering of field cane, bagasse, and factory trash.
    - Rigid control of handling and storage of fibrous fuel, including closed circuit TV to insure continuously regulated supply to boiler.
2. Interfacing of highly sophisticated control equipment to assure attainment of pollution abatement goals together with required reliability to the electric utility for 48 continuous weeks per year.
    - Centralized-control operation with boiler-turbine-generator panel.
    - Bagasse and ash handling control coordinated with BTG controls.
3. Incorporation of safeguards heretofore unnecessary in the industry:
    - Full demineralization of boiler make-up water.
    - Separate distillation of main steam desuperheating water.
    - Automatic monitoring of condensates and immediate rejection of any which are contaminated.
    - Employment of three condensate storage tanks instead of one, for isolation of potential contamination.
4. Employment of the highest pressure bagasse fired boiler in the U.S., at 1250 PSI at 330,000 pounds per hour. (The second largest of its kind in the world.)
    - At normal top pressure of 450 PSI for present sugar mill operation, power plant cycle efficiency would be approximately 46.5%. This would rule out the feasibility of commercial electric power exportation, and also make a profitable sugar operation impossible under the existing pollution regulations.
    - At 1250 PSI, the power plant cycle efficiency becomes approximately 59%, which is required to insure profitable use of the fibrous fuel and minimize the potential requirement for supplementary fossil fuel. Note that

the cooling water for the condensers comes from deep wells near the coast which (as shown in Figure 7) intercept the flow of fresh water to the sea from the Ghyben-Hertzberg lens. The unique location and character of these wells precludes damage to either the lens or to planktonic organisms which are usually entrained in coastal cooling water sources.

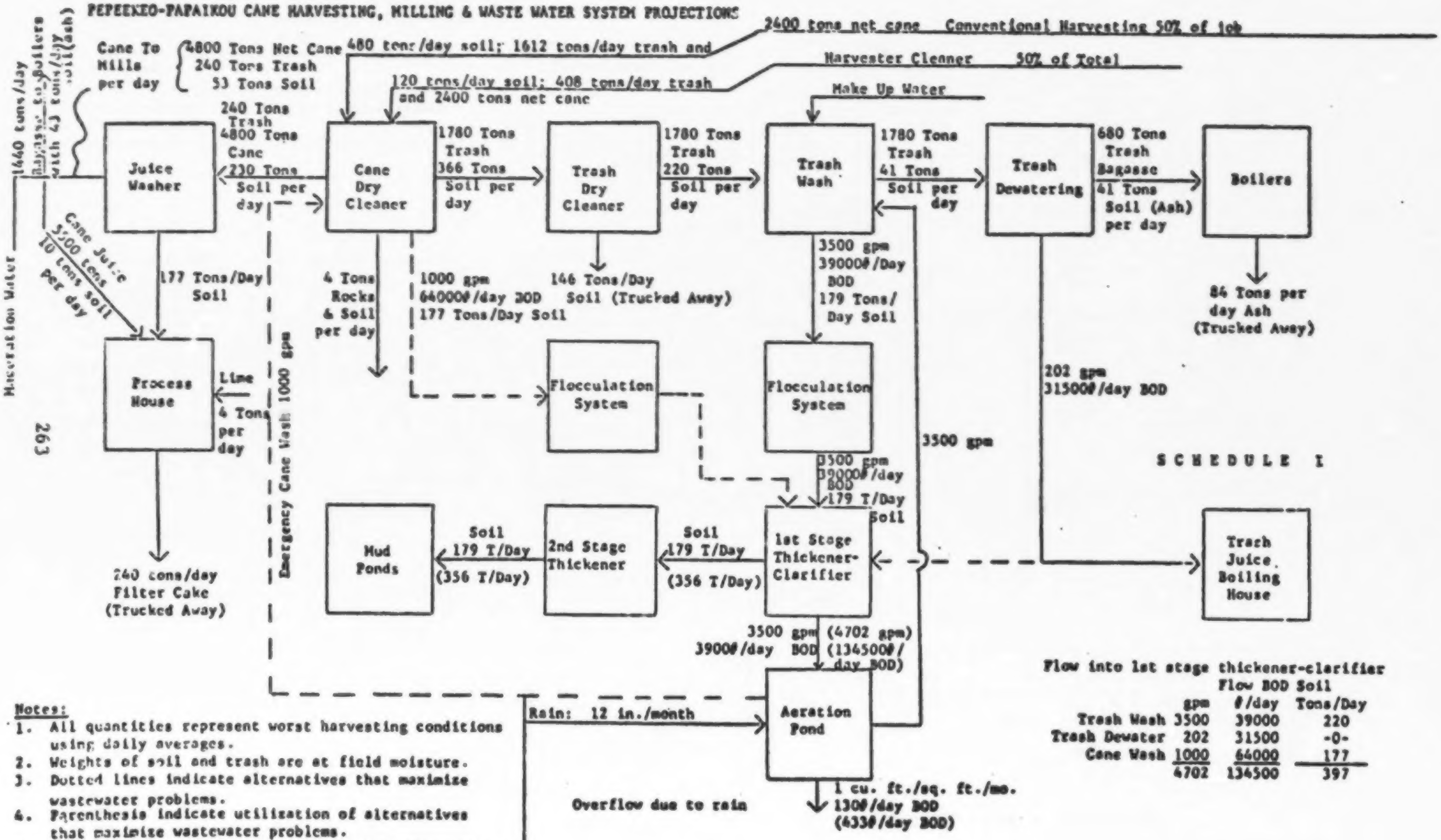
5. Employment of the most thorough and costly operator selection and training program so far attempted in the industry.

Use of agricultural wastes for power generation will reduce the need for fossil fuel power generation plants with the danger of oil spills and noxious air pollution associated with petroleum combustion. Successful implementation of this program should demonstrate to Hawaii public utilities that a dependable source of power is available which can materially contribute to the self-sufficiency of the Hawaiian Islands. Too, it should demonstrate to developing nations the efficacy of using an often common but unused resource which can substantially reduce their foreign exchange requirements for imported oil.

SUMMARY

Possible injunctive action against the Hilo-Hamakua Coast sugar plantation ocean discharge by the Environmental Protection Agency has accelerated development of cleaner harvesting, transporting, soil removal and fibrous waste disposal methods. The net result is a systematic approach beginning with cane harvesting and material handling which includes a new cutting machine and a cane pickup-cleaning machine which makes the first step in preventing initial contact between cane and soil. In the second step cane arriving at the mill is to be dry cleaned with air blasts and mechanical devices to remove leaf trash and soil. The third step consists of a newly invented method of washing the cane with recycled cane juice which will completely replace water except under extreme muddy field conditions. Any emergency wash water (within limits) used will be transferred to the cane trash wash water used to remove soil from the cane trash prior to its use as fuel for electrical power generation. They will also comingle with trash squeezings resulting from the trash dewatering process. The fibrous wastes recovered from the dry cleaner and bagasse are to be used as the fuel source for a high pressure boiler system (1250 psi) designed to meet 20% of the island of Hawaii's power demand. Major benefits from this plant, the first of its kind, include reduction in the amount of fuel oil imported to Hilo for power generation while at the same time meeting State and Federal air compliance regulations and preventing an increase of fossil fuel air pollutants in the county. The wash water is passed through a recycled water cleaner-system which will include a unique clarification-concentration method and a soil dewatering-disposal system designed to prevent slope failure on steep terrain under high rainfall conditions. Progress to date on the Harvester-Cleaner Transporter system has been satisfactory to the extent that a prototype machine is now undergoing extensive testing. The most significant part of the entire program is the soil recovered at various points in the process including the fly ash arrestors in the stack will be returned to the field otherwise stemming the loss of Hawaii's most valuable resource. Figures 21 and 22 summarize the waste quantities accumulating under differing harvest conditions. During

PEPEEKEO-PAPAIKOU CANE HARVESTING, MILLING & WASTE WATER SYSTEM PROJECTIONS


2400 tons net cane Conventional Harvesting 50% of job
480 tons/day soil; 1612 tons/day trash and
Harvester Cleaner 50% of Total
120 tons/day soil; 408 tons/day trash and 2400 tons net cane
Make Up Water
Cane To Mills per day
4800 Tons Net Cane
240 Tons Trash
53 Tons Soil
1440 tons/day Maceration Water
Bagasse to Boilers with 43 tons/day soil (ash)
Juice Washer
240 Tons Trash
4800 Tons Cane
230 Tons Soil per day
Cane Dry Cleaner
1780 Tons Trash
366 Tons Soil per day
Trash Dry Cleaner
1780 Tons Trash
220 Tons Soil per day
Trash Wash
1780 Tons Trash
41 Tons Soil per day
Trash Dewatering
680 Tons Trash Bagasse
41 Tons Soil (Ash) per day
Boilers
84 Tons per day Ash (Trucked Away)
Cane Juice 3500 tons
10 tons soil per day
177 Tons/Day Soil
Process House
Lime
4 Tons per day
240 tons/day Filter Cake (Trucked Away)
4 Tons Rocks & Soil per day
1000 gpm
64000#/day BOD
177 Tons/Day Soil
146 Tons/Day Soil (Trucked Away)
3500 gpm
39000#/Day BOD
179 Tons/Day Soil
Flocculation System
Flocculation System
202 gpm
31500#/day BOD
3500 gpm
3500 gpm
39000#/day BOD
179 T/Day Soil
SCHEDULE I
Trash Juice Boiling House
Emergency Cane Wash 1000 gpm
Mud Ponds
Soil
179 T/Day
(356 T/Day)
2nd Stage Thickener
Soil
179 T/Day
(356 T/Day)
1st Stage Thickener-Clarifier
3500 gpm
3900#/day BOD
(4702 gpm)
(134500#/day BOD)
Rain: 12 in./month
Aeration Pond
Overflow due to rain
1 cu. ft./sq. ft./mo.
130#/day BOD
(433#/day BOD)

Notes:

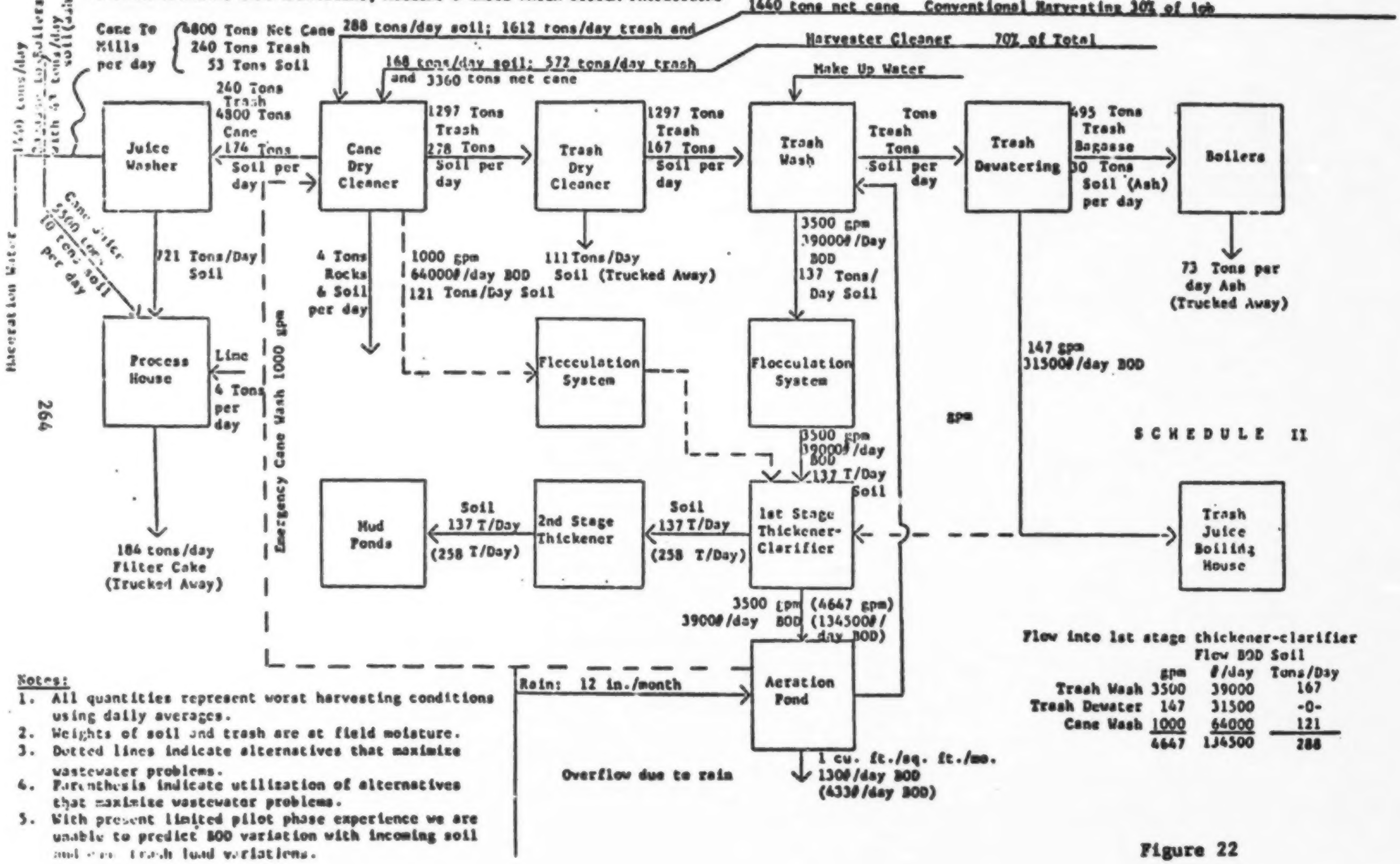
1. All quantities represent worst harvesting conditions using daily averages.
2. Weights of soil and trash are at field moisture.
3. Dotted lines indicate alternatives that maximize wastewater problems.
4. Parenthesis indicate utilization of alternatives that maximize wastewater problems.
5. With present limited pilot phase experience we are unable to predict BOD variation with incoming soil and cane trash load variations.

Flow into 1st stage thickener-clarifier

	Flow gpm	BOD #/day	Soil Tons/Day
Trash Wash	3500	39000	220
Trash Dewater	202	31500	-0-
Cane Wash	1000	64000	177
	4702	134500	397

Figure 21

PEPEEKEO-PAPAIKOU CANE HARVESTING, MILLING & WASTE WATER SYSTEM PROJECTIONS


1440 tons net cane Conventional Harvesting 30% of Job
Harvester Cleaner 70% of Total
288 tons/day soil; 1612 tons/day trash and
168 tons/day soil; 572 tons/day trash and 3360 tons net cane
Make Up Water
Cane To Mills per day
4800 Tons Net Cane
240 Tons Trash
53 Tons Soil
1440 tons/day
Bagasse to Boilers
with 43 tons/day soil(ash)
Maceration Water
Juice Washer
240 Tons Trash
4800 Tons Cane
174 Tons Soil per day
Cane Dry Cleaner
1297 Tons Trash
278 Tons Soil per day
Trash Dry Cleaner
1297 Tons Trash
167 Tons Soil per day
Trash Wash
Tons Trash
Tons Soil per day
Trash Dewatering
495 Tons Trash Bagasse
30 Tons Soil (Ash) per day
Boilers
73 Tons per day Ash (Trucked Away)
Cane Juice
5500 tons
10 tons soil per day
721 Tons/Day Soil
Process House
Lime
4 Tons per day
184 tons/day Filter Cake (Trucked Away)
4 Tons Rocks & Soil per day
1000 gpm
64000#/day BOD
121 Tons/Day Soil
111 Tons/Day Soil (Trucked Away)
3500 gpm
39000#/Day BOD
137 Tons/Day Soil
Flocculation System
Flocculation System
147 gpm
31500#/day BOD
gpm
3500 gpm
39000#/day BOD
137 T/Day Soil
Emergency Cane Wash 1000 gpm
Mud Ponds
Soil
137 T/Day
(258 T/Day)
2nd Stage Thickener
Soil
137 T/Day
(258 T/Day)
1st Stage Thickener-Clarifier
Trash Juice Boiling House
3500 gpm
3900#/day BOD
(4647 gpm)
(134500#/day BOD)
Rain: 12 in./month
Aeration Pond
Overflow due to rain
1 cu. ft./sq. ft./mo.
130#/day BOD
(433#/day BOD)

SCHEDULE II

Flow into 1st stage thickener-clarifier

	Flow gpm	BOD #/day	Soil Tons/Day
Trash Wash	3500	39000	167
Trash Dewater	147	31500	-0-
Cane Wash	1000	64000	121
	4647	134500	288

Notes:
1. All quantities represent worst harvesting conditions using daily averages.
2. Weights of soil and trash are at field moisture.
3. Dotted lines indicate alternatives that maximize wastewater problems.
4. Parenthesis indicate utilization of alternatives that maximize wastewater problems.
5. With present limited pilot phase experience we are unable to predict BOD variation with incoming soil and [illegible] trash load variations.

Figure 22

adverse conditions, wet weather, steep slope or both,conventional harvesting would be used 50% of the time. Otherwise 70% is to be harvested with the new equipment and 30% (steep slopes and gullies) by conventional means. The BOD values are very rough estimates. We really have no clear idea what the levels can be with all systems operational.

ACKNOWLEDGEMENTS

This report is not the work of any one or two authors. It represents the collective effort of several engineers most notably Charles Hart and Clarence Montgomery and Virgil Hendricks of C. Brewer and Company, Limited, Engineering Department for harvester development; Lane S. Thompson, Dr. James Kumagai and James Honke, Consultants from Sunn, Low, Tom and Hara, Inc. on water treatment; Melvin Tanaka of W. A. Hirai & Associates, Inc. for dry cleaner and juice washer development and finally, William Blockley and Richard Webb of Hilo Coast Processing Company for power plant development.

Hilo Coast Processing Company is particularly grateful for the financial assistance made possible by the Environmental Protection Agency. Ken Dostal of the Pacific Northwest Water Laboratory together with Russel Freeman, Charles Seeley and other EPA personnel from Region IX have been extremely helpful in their advice and encouragement on this project.

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PRACTICAL APPLICATION OF A BIOLOGICAL/PHYSICAL/CHEMICAL TREATMENT SYSTEM TO MEAT PACKING WASTEWATER

by

Gilbert F. Hill,* Glenn W. Dunkelberger, Jr.*

INTRODUCTION

The meat packing industry has received considerable attention in the area of pollution control. There are many varied treatment systems employed by the industry, but by far the most utilized mode of treatment has been biological in nature. Activated sludge, aerobic and anaerobic lagoons, trickling filters, rotating contactors, as well as the channel aeration process have been satisfactorily utilized. Air flotation, using coagulating agents, as well as the common "catch basin" process represent the major processes in the area of physical and chemical treatment.

We at Gilbert Associates, Inc. have had the opportunity to work with the Roberts Packing Company as consulting engineers for the operation of their unique waste treatment system. As system consultants, we have observed and evaluated Roberts' biological, physical, and chemical unit process oriented waste treatment system. It is felt that by examining this approach to waste treatment, the advantage in the utilization of a combination of treatment modes (i.e. biological/physical/chemical) can be realized.

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The Roberts Packing Company is engaged in the manufacture and sale of pork and pork products such as ham, bacon, frankfurters, bologna and scrapple. In the past Roberts slaughtered an average of 750 hogs per day for two days a week, and processed pork products five days a week. Presently, slaughtering is not performed at the plant, and the plant devotes five days a week to the processing of 50,000 pounds of pork products per day. The major sources of wastewater are: 1. Carcass washdown; 2. Scalding wastes; 3. Screened dehairing wastes; 4. Cooling waste; 5. Smoke house wastes; 6. Meat cooking and general clean-up wastes.

WASTEWATER TREATMENT

Wastewater treatment consists of 4 unit operations which are presented in Figure 1 - Waste treatment flow diagram. 1) Flotation of insoluble grease in catch basins. 2) Chemical treatment using ferrous sulfate and chlorinated lime. 3) Primary - rapid filtration through leelite sand filters. 4) Secondary - slow filtration through biological leelite sand filters. The raw waste biochemical oxygen demand concentration ranges from 2400 mg/l to 1500 mg/l on the average, corresponding with average suspended solids concentrations of 1400 mg/l to 1000 mg/l on kill and non-kill days, respectively. The first treatment process, separation of floatable greases, is basically a physical unit operation.

Grease Removal

The catch basins are rectangular basins which provide an average of 1.5 hours retention time. This retention time, in addition to adequate surface area, allows most of the floatable material to collect on the

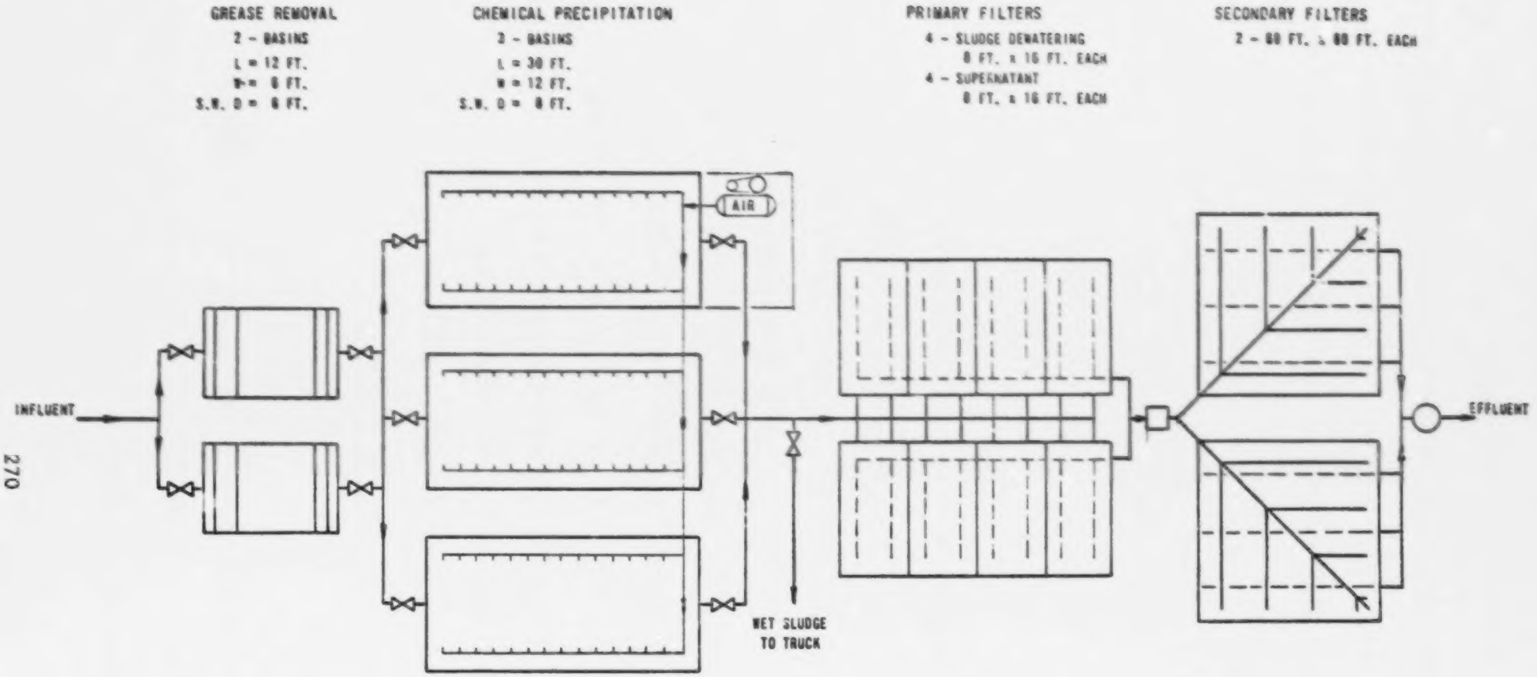
GREASE REMOVAL
2 - BASINS
L = 12 FT.
W = 8 FT.
S.W. D = 6 FT.
CHEMICAL PRECIPITATION
3 - BASINS
L = 30 FT.
W = 12 FT.
S.W. D = 8 FT.
PRIMARY FILTERS
4 - SLUDGE DEWATERING
8 FT. x 16 FT. EACH
4 - SUPERNATANT
8 FT. x 16 FT. EACH
SECONDARY FILTERS
2 - 80 FT. x 80 FT. EACH
INFLUENT
AIR
WET SLUDGE
TO TRUCK
EFFLUENT

FIGURE I WASTE TREATMENT FLOW DIAGRAM

surface of the basins. All material with specific gravities less than water do not float to the surface since the retention time may not be of sufficient length to allow slow rising materials to reach the surface. Also, some lighter than water material may be characterized by having surface charges rendering these particles hydrophilic in nature. A definite advantage in removing the floatables as a first step in treatment is that it is sold as a renderable material. One hundred gallons of material is daily skimmed from the catch basins and placed in barrels. The size of the plant does not warrant mechanizing this operation. The waste flow leaves the catch basins and enters one of three 20,000 gallon batch operated chemical treatment tanks.

Chemical Precipitation

When a tank is filled, the content of the tank is mixed using diffused air. Chemical dosages typically used are: 100# lime, 100# ferrous sulfate, and 25# of chlorinated lime. Following chemical addition, the tank is mixed for a minimum of 10 minutes, and allowed to quiescently settle for approximately 3 hours. By use of a series of discharge ports located at various depths in the tank, the treated wastewater is directed to the next treatment step. The sludge resulting from the chemical treatment and accumulated at the bottom of the tank is discharged by gravity to a tank truck for land disposal. The actual chemical dosages, mixing time, and settling time are varied by the waste treatment plant operator. The system is manually operated and the experienced operator adjusts process variables according to the varying waste loads encountered during operation. Factors such as color and general appearance are used in determining the chemical treatment requirements. Using the above mentioned method of chemical treatment, this unit has shown biochemcial oxygen demand reductions of 50% on an average. Suspended solids are removed to levels averaging 95%. Total phosphate reductions of up to 95% have been found for the chemical treatment step as well as the other mentioned reductions. Typical non-kill day chemical treatment effluent is characterized as follows: 750 mg/l biochemical oxygen demand, 50 mg/l suspended solids, and 20 mg/l total PO_4. A significant chemical factor which creates this reduction is the process of coagulation. The calcium and iron ions and their associated charged molecules reduce the surface potential of the particles rendering them susceptible to gravitational forces. Precipitants of the coagulating ions also tend to encircle, or enmesh, particles contained in the wastewater resulting in the combination of the particle and coagulating ion group being able to settle by gravity. Although the exact means of reduction of biochemical oxygen demand, suspended solids and total PO_4 has not been totally established, the above postulations are rational explanations. After chemical treatment, the supernatant from the 20,000 gallon tanks is further treated by rapid sand filtration on primary filters.

Primary Filtration

The primary filters are constructed of leelite sand with an underdrain collection system. The filters function to reduce the suspended solids and any solids associated biochemical oxygen demand present in the waste flow. A set of four filters is used alternately providing for time to dewater and clean each filter as required. The chief function of these filters is to remove carry-over precipitant and suspended solids from the chemical treatment step. When wet sludge from the chemical precipitation tanks is trucked for disposal, the four filters provided for sludge dewatering are used for supernatant filtration.

Any possibility of biological growth in these filters is eliminated by a slight chlorine residual in the flow, as well as the hydraulic loading rates utilized. The filters are flooded, which prevents oxygen penetration from the atmosphere. Also, the relatively short detention time of the flow in the filters results in creating unfavorable conditions for biological growth. The effluent from these filters, which constitutes influent to the next unit process, typically is characterized by the following values: 500 mg/1 biochemical oxygen demand and 20 mg/1 suspended solids.

Secondary Filtration

The final unit in the system is that of biological filtration. These filters are of leelite sand construction with an underdrain system. Unlike the filters used for physical removal of solids, the biofilters are designed to allow the slow drainage of flow through the sand media. A relatively large surface area, and a multi-point influent system provide for the low hydraulic loading rate. Due to this low loading rate, oxygen from the atmosphere is permitted to come in contact with the filter media. Also, the detention time of an increment of flow, relative to the sand media is comparitively long. The factors of oxygen availability and detention time promote biological growth on and in the filters with average biochemical oxygen demand removals of 90%. The exact biota involved in the secondary filters is not known. It would seem logical to assume the culture would be similar to that found on trickling filters. The total system consistently produces effluent reflecting over-all reductions of: 95% biochemical oxygen demand, 95% suspended solids, 95% total phosphate.

MERITS OF MULTI-MODE TREATMENT

The system utilized at Roberts has been presented to show the applicability of combining several modes of treatment into a workable system. The merits of a multi-mode waste treatment system for Roberts Packing starts with the use of the physical separation and recovery of grease from the flow in the catch basin units. The ultimate sludge disposal problem is partially reduced through disposal of the recovered material to a rendering plant. This also has a secondary but inviting advantage of providing some revenue. The chemical treatment step has several merits, depending on one's point of view.

By reducing the organic strength of the waste, any biological units following the chemical treatment need not be sized as large as if they were designed to treat the raw waste. Chemical treatment also has the advantage of requiring only a relatively short time for reduction of the waste load. Correspondingly, land space can be less for chemical treatment, than for biological treatment. As in the case at Roberts, chemical addition feasibly cannot generally remove the total waste load present.

With significantly reduced waste loads, biological treatment functions to further remove pollutants to satisfactory levels. Although the system at Roberts' has produced excellent results, each waste treatment problem must be investigated with an open mind in order to provide the most efficient and economical system.

It is hoped that this brief presentation has indicated the merits of using biological/physical/chemical treatment modes. With the ever increasing demand for "clean" water, the task of the waste treatment system designer is to investigate all available methods of treatment. It is felt that in too many cases, industrial waste treatment systems have been designed with the assumption that biological treatment is the only feasible mode. The use of biological treatment is not the issue, but the advantage in using physical and chemical processes in connection with biological units is the key point. Although the system in use at Roberts is almost 20 years old, it's ability to meet the present water quality criteria dramatically indicates the advantages of a multi-mode waste treatment system.

SMALL MEAT-PACKERS WASTES TREATMENT SYSTEMS

by

Jack L. Witherow*

INTRODUCTION

The technology reported herein will be helpful to the meat-packing industry, especially the smaller plants, in control and treatment of their wastewaters. The number of establishments processing red meats is about 14,000 of which some 10,000 are estimated to be small plants. A small plant is defined by an annual liveweight kill of less than 25,000,000 pounds. Wastewaters discharged to receiving waters need treatment to meet effluent criteria. Many plants discharge to a municipal treatment system; but, sewer charges and pretreatment regulations require treatment of these discharges also.

The treatment systems investigated were picked to meet requirements that are common in the meat-packing industry. These include: (1) reduction of oxygen demanding material, suspended solids and grease for discharge to a municipal sewer; (2) equivalent secondary treatment for discharge to a surface water; (3) reduction of nitrogen, especially in the ammonia form, and phosphorus. Discharge limitations on nitrogen and phosphorus are becoming common and are expected to be placed on most discharges in the future.

Waste treatment systems for small meat-packers should include the following constraints:

1. The process and operation should be as foolproof as possible.
2. Mechanical equipment should be minimized and designed to prevent undetected failure.
3. Treatment should be easily monitored and meet effluent limits.
4. Design should allow simple construction to reduce cost.

The unit processes demonstrated were designed to reduce and simplify the operation of the treatment system. Small packers do not have personnel trained in the operation of treatment plants. Simple operation is even more important than minimal costs for construction; however, a design which allows plant personnel to undertake construction can reduce costs.

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The facilities used in the development and demonstration project described herein (12060 GPP) are located at the W. E. Reeves Packinghouse on the outskirts of Ada, Oklahoma, about three miles from the Robert S. Kerr Environmental Research Laboratory. The packing company's need to obtain better waste treatment and control facilities and the Research Laboratory's need for a waste source and pilot plant test facilities resulted in a cooperative research effort. Because of limited manpower at the Research Laboratory, East Central State College in Ada, Oklahoma, joined this cooperative project, supplying faculty and students to do the chemical analyses.

The W. E. Reeves Packinghouse produces some 30 items including cut and uncut beef and pork and its own brand of fresh sausage, bacon, weiners, cold cuts, chili, and other meat items. Meat products sold represent about 60 percent of liveweight killed (LWK). Smoked and spiced products are 15 percent of the LWK and processed meats are 25 percent of the LWK. Sales are in the surrounding area mainly to retail groceries and restaurants.

The plant processes 500 to 700 cattle per month and 600 to 800 hogs per month, or about 10 million pounds of live weight annually. The plant is located west of the city on 64 acres of rolling land. An unnamed creek flows north through the property. The prevailing winds are from the south. North of the plant are cattle ranches with the nearest residence 1 1/2 miles distant. South and southwest of the plant the nearest residences are 1/4 mile distant. Besides the processing plant, cattle pens, storage areas for machinery and materials, and parking areas are located on the grounds.

OBJECTIVES

The objectives consist of developing and demonstrating treatment systems selected to meet present and future needs of the meat industry, especially the small meat-packers. The treatment systems are combinations of the following biological processes: anaerobic lagoon, transitional lagoon, stabilization lagoon, aerated lagoon, and spray-runoff irrigation.

The detailed project objectives were grouped into a two-phase investigation. In the first phase which is reported in this paper there were two objectives. The first objective was to demonstrate the anaerobic-aerobic lagoons system to meet the requirement of the small meat-packer for discharge to a municipal sewer and to a stream. This system was selected to demonstrate its simplicity of operation and minimum capital and maintenance cost with high removal efficiencies. The treatment system consisting of an anaerobic lagoon, a transitional lagoon, and a stabilization lagoon was designed to obtain greater than 95 percent BOD removal producing an effluent of less than 50 mg/l. The cost of operation, maintenance and construction was documented. The need for sludge recirculation in the anaerobic lagoon was evaluated since removal of the recirculation pump would result in a system without a moving part, thereby greatly reducing operating requirements. The three lagoons were evaluated separately as one or two lagoons were expected to meet requirements for discharge to a municipal system. The second objective was to develop and demonstrate the spray runoff irrigation process to meet requirements for 80 percent removal of nitrogen and phosphorus. This process system was demonstrated in series with the anaerobic lagoon.

In the second phase there are also to be two objectives; one of which is to continue evaluation of the spray runoff irrigation process using both effluent from the aerated lagoon and raw wastewater for nitrogen and phosphorus removal. The other objective is to develop and demonstrate the economic and technical advantage of an all aerobic lagoon treatment system. This is critical where hydrogen sulfide odors will create a nuisance or where low ammonia limits are imposed. The anaerobic lagoon is to be converted to an aerated lagoon. Operation will be on a batch basis with discharge occurring after settling conditions are applied. Operation of the mechanical parts of the system is to be automated to meet the small meat-packer's needs. The second and third aerobic lagoon will be evaluated separately to demonstrate the different levels of removals obtainable. The aerated lagoon is expected to meet requirements for discharge to a municipal system. The two or three lagoon treatment systems are expected to meet requirements for discharge to surface waters.

DESIGN

The design procedure is described in detail for the small meat-packer and is divided into preliminary design and detailed design. Preliminary design includes measure of the wastewater, selection of suitable treatment systems, sizing of the unit process, and review by the regulatory authorities. Detail design includes the preparation of plan, specification and modifications during construction.

Preliminary Design

The W. E. Reeves Packinghouse wastewaters come from the slaughtering area, the meat processing areas, the lavatory, the hide storage cellar, and the holding pens. The major waste load is from slaughtering which is a one-shift operation, Monday through Friday. Meat processing is on a 5 1/2 day basis. The hide cellar is emptied and flushed once a month and the holding pens are dry cleaned and then flushed on Saturday.

Wastewater flows and concentrations were both measured. Eight hourly samples were taken and composited during slaughtering/processing on May 19, 1970, and on June 9, 1970. A grab sample was taken on June 19, 1970. The samples were analyzed according to Standard Methods. The data are tabulated in Table 1

Table 1. Wastewater Chemical Anaylses for Preliminary Design

Item (mg/l)	May 19, 1970	June 9, 1970	June 19, 1970
BOD	2680	1352	1165
Grease	1823	434	-
TKN	-	108.5	110
NH_4-N	-	15.5	10
NO_2-N	-	0.18	-
NO_3-N	-	0.24	-
Total P	-	31.4	-

The BOD and grease data exhibits the variation normally found in slaughterhouse wastes which are reported as 650 to 2200 mg/l and 200 to 1000 mg/l, respectively (2). A weighted average BOD concentration of 2000 mg/l was selected for design purpose. The temperature of the wastewater was 25° to 28° C. There is sufficient nitrogen and phosphorus for biological treatment. To measure flow, a Parshall flume with a 3-in. throat was installed with a flow meter. The flow on killing days and Saturday is tabulated in Table 2. A flow of 15,000 gallon/day was used for design purposes.

Table 2. Wastewater Flow Analyses for Preliminary Design

Date		Flow (gallon)	Operating Period (hrs)
6/18/70	Thursday	19,152	8
6/19/70	Friday	15,072	8
6/20/70	Saturday	2,495	3
6/22/70	Monday	14,040	9
6/23/70	Tuesday	15,498	9
6/24/70	Wednesday	14,274	10
Total	1 week	80,531 gallons	47 hours

A tour of the packinghouse land revealed several potential sites for a treatment system. The sites adjacent to the plant were used for holding and feed pens, and storage of materials and equipment. The site selected was in a pasture and solid waste disposal area 300 feet west of the plant. This site permitted a gravity flow system eliminating the necessity for pump maintenance and operation. The disadvantages were land slope and a conglomerated rock layer immediately under the surface. The site had sufficient land available for selection of an anaerobic-aerobic lagoon system. The trade off of land value for the costs of concrete and steel in more compacted systems was possible, and the lagoons could be constructed by plant personnel to reduce cost.

The anaerobic-aerobic lagoon system has obtained greater than 90 percent first stage BOD reduction with highest removals during the critical hot summer. Outside of the desired minimum capital and operating costs, the system is simple to operate and shows visible treatment results; mechanical equipment can be held to a minimum to prevent failures; and the treatment processes can withstand the typical shock loading of the meat-packing industry.

The anaerobic process is especially suited to this concentrated hot waste. Schroeffer (3) demonstrated 90 percent BOD removal at very high loading of 0.25 lb/cu ft/day at 30°C and at 0.10 lb/cu ft/day at 25°C in a constant temperature reactor. More recent developments have shown the suitability of the anaerobic lagoon (4)(5)(6). State regulatory agencies in Illinois, Iowa, Nebraska, Tennessee, Pennsylvania, and Minnesota accept design loadings of 15 lb BOD/1000 cu ft of anaerobic ponds allowing 60 percent BOD removal. Using a sludge recirculation system, Hester (7) obtained an average of 80 percent removal with loading of 9.6 to 12 lb/1000 cu ft/day and sludge recirculation ratio of 2 to 1. After the first year's operation, BOD removals continually exceeded 90 percent.

The anaerobic lagoon has given high removal efficiency with and without sludge recirculation. The benefits of sludge recirculation have not been established (4)(8). Elimination of sludge recirculation could result in a reduction of costs and simplifying operation, an especially desirable factor for small meat-packers. In some cases, a sulfate concentration of over 200 mg/l in the water supply has resulted in objectionable hydrogen sulfide odor production in the anaerobic pond. Additionally, the anaerobic pond reduces the protein (Kjeldahl nitrogen) to ammonia which is also toxic to fish.

Following the anaerobic pond, a variety of aerobic processes have been utilized (8). A two-stage aerobic lagoon process was selected. For the small plant, the aerobic lagoon offers the advantage of simple operation. The one- and two-stage aerobic lagoon systems have been successfully applied (4)(6)(7) both with and without mechanical aeration of the first stage. The first stage aerobic lagoon is considered a transition pond and the second a stabilization pond. Successful operation was achieved with organic loadings up to 130 lb of BOD/day/acre on one stage (4) and 113 and 56 lb BOD/day/acre for 1st and 2nd stages, respectively (7). A design factor developed by Coerver (6) for small packers is based on the number of beef cattle killed multiplied by three plus the number of hogs killed; pond design is then based on this "equivalent" number of hogs killed. The design loading in Louisiana is 800 hogs/week/acre ft in the anaerobic pond and 690 hogs/week/acre of surface area in two aerobic ponds in series. With a waste load of 2.5 lb BOD_5/hog and a 5-day per week killing operation, this is equivalent to 9 lb BOD_5/day/1000 cu ft on the anaerobic pond. Assuming an 80% removal in the anaerobic pond, the equivalent loading on the aerobic lagoons would be 70 lb BOD_5/day/acre.

The anaerobic-aerobic lagoon system selected will not meet the future needs for reduction of nitrogen and phosphorus. To meet future needs, the spray runoff irrigation system was selected in combination with the lagoon system. Spray runoff systems have been used successfully for a variety of wastewaters including those from paper mills, canneries, and municipalities (9)(10)(11). Spray runoff systems are being used successfully under both intermittent application (9) and continuous application (10). A recent study showed that spray runoff treatment of a cannery wastewater reduced the BOD by 99 percent, total nitrogen by 91 percent, and total phosphorus by 88 percent (12).

After process selection, a preliminary design and layout sketch of the anaerobic-aerobic lagoon system was prepared and submitted to the Oklahoma Water Resources Board for their review prior to detailed design and construction.

Detailed Design

To determine exact location of the ponds, a detailed topography survey of the site was made which included depth of soil. The limited soil at the site was mainly composed of decayed paunch contents and hair and was unsuitable for dike construction. A suitable clay soil that was being stripped to obtain underlying sand was purchased from a quarry at about a half mile hauling distance from the site. The conglomerate rock at the site was from three inches to two feet under the surface. Dike height and the underlying rock were the controlling factors in location. Fortunately, one of two potential locations for the deep anaerobic pond was in a draw which would allow construction of a pond with eight to ten feet water depth without rock excavation. To maintain a minimum of three feet depth in the stabilization and transitional ponds for weed control required rock removal. The ponds were drawn on the topography map at several elevations to calculate minimum cost of rock cut and dike fill. As a result, the ponds were located as far up the slope as possible without eliminating a gravity flow system. The maximum amount of rock cut was 1.5 feet and maximum centerline height of the dike was 13 feet. A layout of the treatment system drawn to scale is shown in Figure 1.

The 550 feet of 6-inch sewer line was located to minimize rock excavation and to go around an existing barn. The pipe was sloped at 0.9 ft/100 ft. Vitrified clay pipe was used, except under the roadway where steel pipe was used. A manhole was located where the plant sewers intersected and at each change in pipe direction to permit cleanout and inspection. An extra manhole was located on the raw waste line to house sampling and flow recording equipment. In each manhole the outlet invert was set 0.1 feet lower than the inlet invert. A difference of 0.5 feet was set between the outlet in manhole No. 5 and the water level in the anaerobic pond. This energy drop was to prevent plugging of the 6-inch pond inlet pipe. The end section of this inlet pipe was set on a small pad of concrete to prevent scarring of the bottom and slippage of the pipe down the steep slope of the anaerobic pond dikes. The insert in Figure 1 of the manhole and piping layout gives details of piping arrangements.

The detail of manhole No. 5 is shown in Figure 2. Manholes No. 1, 2, 3 and 6 were similarly constructed. The square shape and other details were designed to simplify construction. Manhole No. 5 is the structure controlling bypass of the anaerobic pond. By inserting a wooden gate, flow can be diverted to manhole No. 6. At manhole No. 6, a similar gate arrangement allows diversion of flow to either the transitional pond or to the receiving stream. This bypass arrangement was used after the anaerobic pond was completed and prior to completion of the other two ponds to obtain treatment in part of the system prior to completion of the entire system.

The outlet pipe was located two feet below the surface of the anaerobic pond to prevent the scum blanket from blocking the pipe inlet. The pipe entered manhole No. 6 one foot below the water level to eliminate scrubbing of gases which occur at an overflow weir. The water level in the pond was controlled by the elevation of the outlets in manhole No. 6.

The 6-inch inlet pipe to the transitional pond was extended to discharge to the deepest portion of the pond. This deep discharge was designed to reduce odor emission and to aid in forming an anaerobic zone under the aerobic zone. The transitional and stabilization ponds were connected by a steel pipe. This

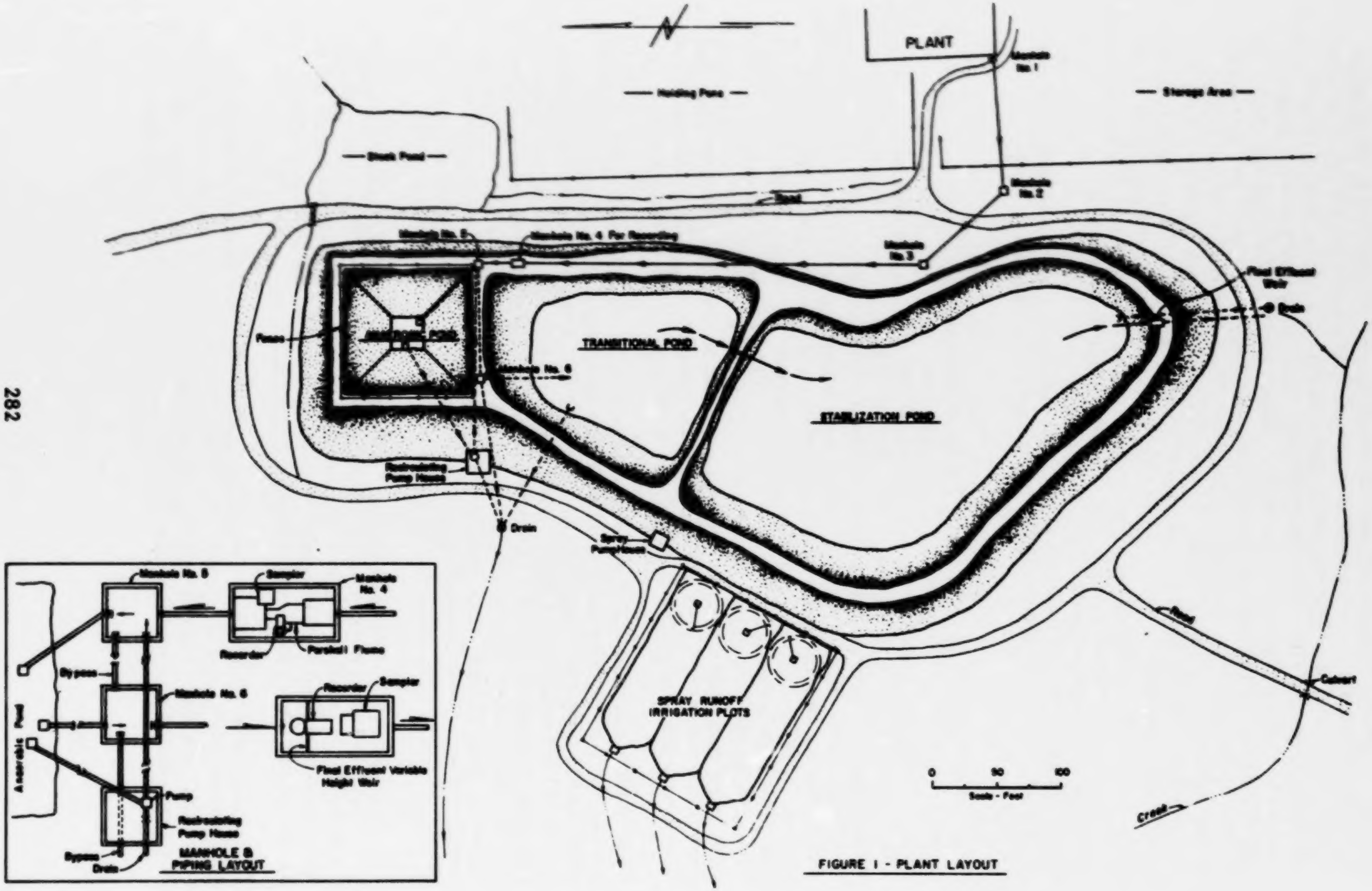
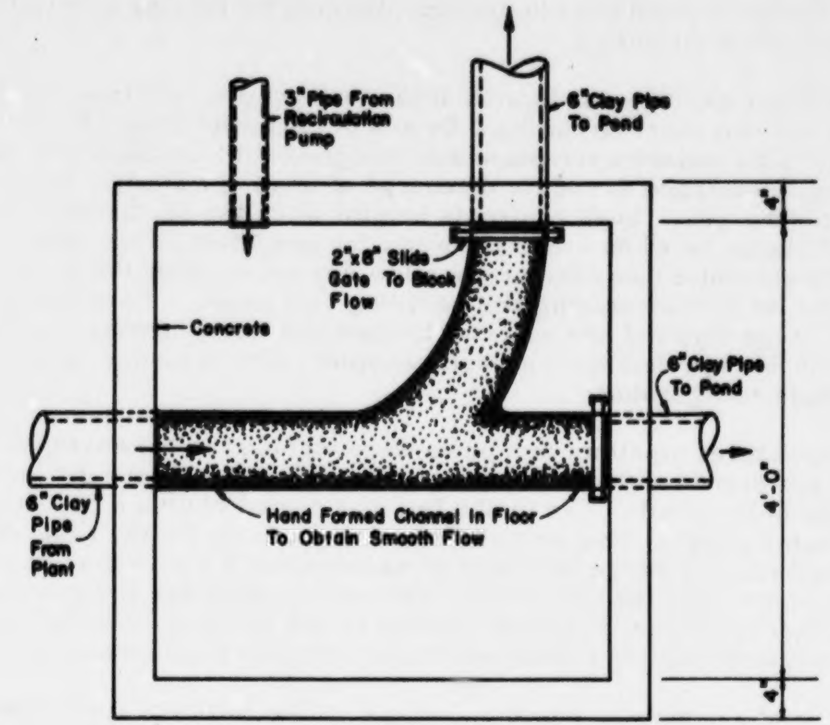

N
PLANT
Manhole No. 1
Holding Pond
Storage Area
Stock Pond
Road
Manhole No. 2
Manhole No. 5
Manhole No. 4 For Recording
Manhole No. 3
Final Effluent Weir
Drain
Fence
TRANSITIONAL POND
Manhole No. 6
STABILIZATION POND
Recirculating Pump House
Drain
Spray Pump House
SPRAY RUNOFF IRRIGATION PLOTS
Road
Culvert
0
50
100
Scale - Feet
Creek
Manhole No. 5
Sampler
Manhole No. 4
Recorder
Parshall Flume
Bypass
Manhole No. 6
Recorder
Sampler
Anaerobic Pond
Final Effluent Variable Height Weir
Pump
Recirculating Pump House
Bypass
Drain
MANHOLE & PIPING LAYOUT

FIGURE 1 - PLANT LAYOUT


3" Pipe From Recirculation Pump
6" Clay Pipe To Pond
2"x8" Slide Gate To Block Flow
Concrete
6" Clay Pipe To Pond
6" Clay Pipe From Plant
Hand Formed Channel In Floor To Obtain Smooth Flow
4"
4'-0"
4"

TOP VIEW

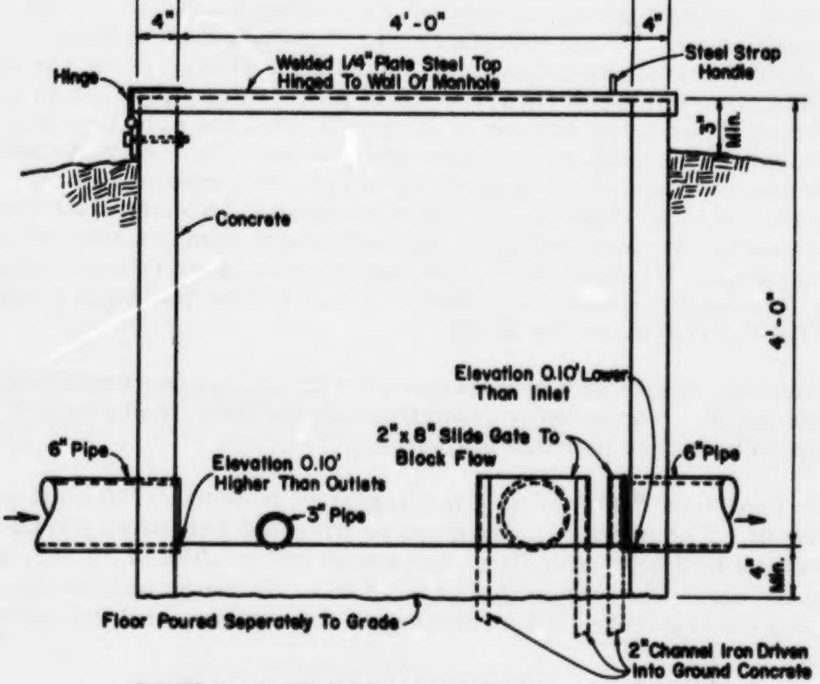

4"
4'-0"
4"
Hinge
Welded 1/4" Plate Steel Top Hinged To Wall Of Manhole
Steel Strap Handle
3" Min.
Concrete
4'-0"
Elevation 0.10' Lower Than Inlet
2" x 8" Slide Gate To Block Flow
6" Pipe
Elevation 0.10' Higher Than Outlets
3" Pipe
6" Pipe
4" Min.
Floor Poured Seperately To Grade
2" Channel Iron Driven Into Ground Concrete Poured Around

FIGURE 2 - INLET & BYPASS MANHOLE

pipe was located at one foot below the water surface, at the furthest point from the transitional pond inlet to prevent plugging by floating material and to reduce short circuiting.

The final effluent manhole was located at the furthest distance from the inlet of the pond to prevent short circuiting. Details of the outlet structure are shown in Figure 3. This concrete structure was designed with a submerged inlet and a variable weir elevation to reduce discharge of floating materials and permit controlled discharges. Such control is helpful when the discharge is to an intermittent stream or when use of the water for irrigation is planned. The length of the structure was designed to allow dry access from the bank and to provide room for flow measuring and sampling equipment. As depicted in Figure 3, a large plywood box was constructed and installed over the final effluent manhole to protect the composite sampler, flow recorder, and the sample storage refrigerator.

An intake structure, pipeline, and pump were included in the anaerobic pond design. A bar screen with 1-inch openings was placed over the intake structure in the bottom of the pond. The intake line was sloped to give a positive pressure on the pump. This line also serves as a drain for the anaerobic pond. The pump discharge line went to manhole No. 5 where the recirculated sludge was mixed with the raw waste. The mixing of sludge and raw waste and the further mixing of the lagoon content by the increased influent flow were to increase biological activity and improve removal efficiencies.

The selection of a pump was based on volume of flow desired, type of material to be pumped, and price. A recirculation ratio between 1:1 and 2:1 was considered adequate. Based on the design of 15,000 gallons in a 12-hour operating period, a sludge pump capable of delivering 15,000 to 30,000 gallons/day was desired. Five manufacturers of pumps were contacted and requested to submit recommendations and prices for a sludge pump for packinghouse wastes of a nonclog design that could pass solids up to 3/8 inch diameter. The small delivery volume of 20 gpm limited the selection of pumps. Two manufacturers recommended air-operated pumps. The desire to minimize equipment maintenance and the necessity for an air compressor and tank to operate these pumps eliminated further consideration. Two manufacturers recommended nearly identical self-priming centrifugal pumps designed for solids handling with 1 1/2 inch ports, and one manufacturer recommended a screw pump. The unit selected was a Model 11 1/2 A-Gorman Rupp pump with a 1750 RPM 0.5 H.P motor for $350.

The most influential factors in pond design were lb of oxygen demand and minimum water depth. Topography, construction methods, and present structures controlled other features of design.

The anaerobic pond was designed at a loading of 15 lb BOD_5/1000 cu ft with a 9 ft water depth. The pond was designed as inverted truncated pyramid with lengths at the bottom, water line, and centerline of dike of 20, 65, and 88 feet, respectively. The side slope was 2.5 to 1. During construction, water depth was increased to 10 ft without rock excavation, and the as-built

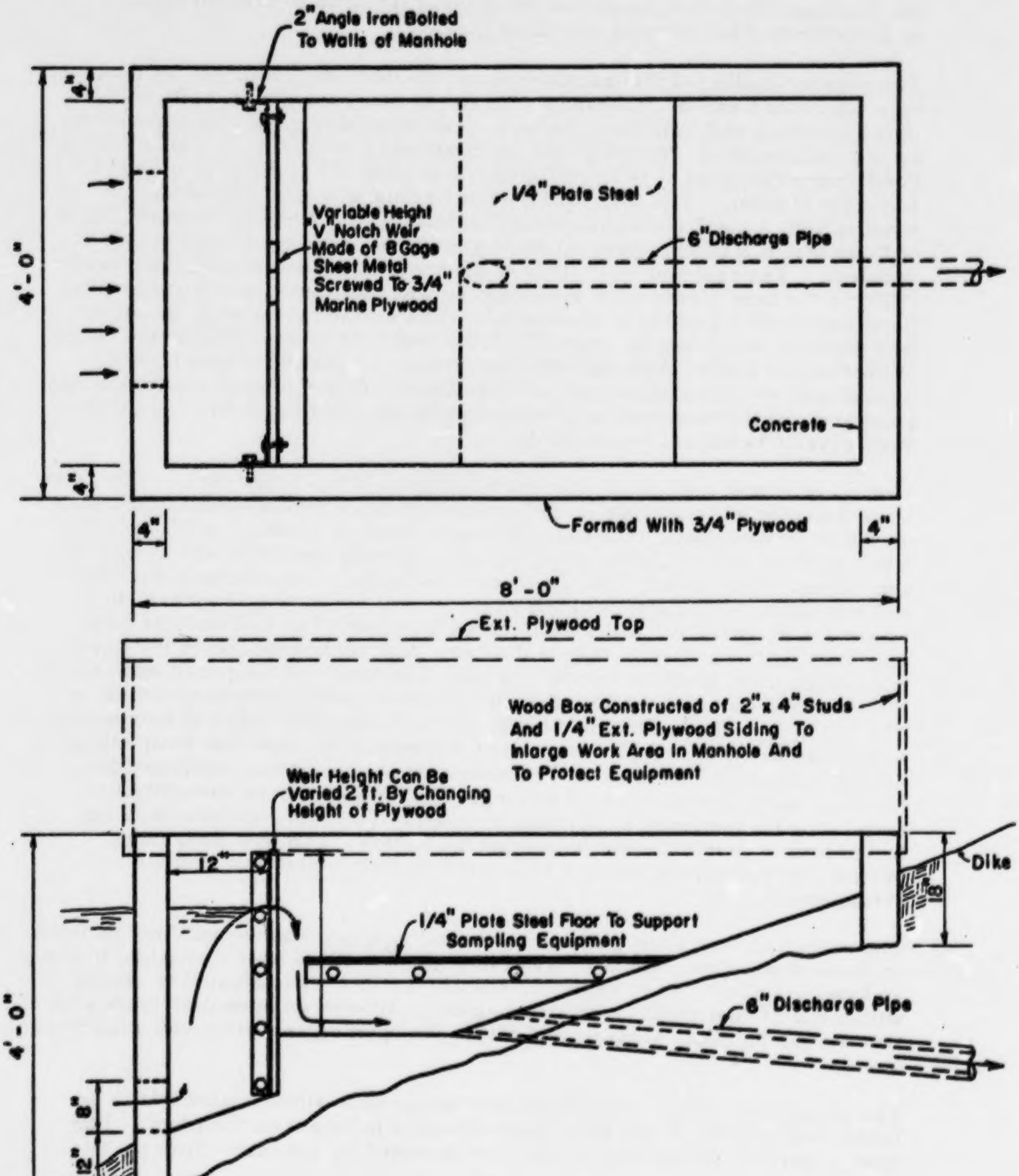

2" Angle Iron Bolted To Walls of Manhole
4"
4"
4'-0"
1/4" Plate Steel
Variable Height "V" Notch Weir Made of 8 Gage Sheet Metal Screwed To 3/4" Marine Plywood
6" Discharge Pipe
Concrete
Formed With 3/4" Plywood
4"
4"
8'-0"
Ext. Plywood Top
Wood Box Constructed of 2" x 4" Studs And 1/4" Ext. Plywood Siding To Inlarge Work Area In Manhole And To Protect Equipment
Weir Height Can Be Varied 2 ft. By Changing Height of Plywood
12"
Dike
8"
1/4" Plate Steel Floor To Support Sampling Equipment
8" Discharge Pipe
4'-0"
8"
12"

FIGURE 3 - FINAL EFFLUENT MANHOLE

anaerobic pond has a volume of 18,500 cu ft. The tops of all dikes were sloped to the outside to prevent rainfall runoff from entering the pond. A six-foot high chain link fence was put around the pond to prevent animals or individuals from entering this deep pond.

The organic loading of the transitional and stabilization ponds can be designed on a combined basis or separately. In either case, the removal efficiency of the previous unit must be estimated. The anaerobic pond was assumed to have an 80% removal efficiency and the combined transitional and stabilization ponds were designed at 50 lb BOD_5/day/acre with 1/3 of the area in the transitional pond. The combined design loading was selected because of success with a similar design used in Louisiana (6). A minimum water depth of three feet was used to prevent weed growth and accompanying mosquito problems. The east and west dikes of the transitional and stabilization ponds followed the land contours. A common dike was used between the anaerobic pond and aerobic pond to save material. The surface areas at 2, 3, and 4 feet minimum water depths are 0.97, 1.06, and 1.15 acres. This is the range of depths that can be obtained with the variable height outlet weir. The transitional pond has 30 percent of these areas. The volume of the transitional pond and stabilization pond at minimum water depth of three feet are 407,000 and 1,144,000 gallons, respectively.

The spray runoff irrigation plots were designed at 0.1 acres each. The plots were designed at pilot scale to limit water use and the effect of this diversion on the other treatment processes. The plots require a smooth surface having 2 to 6 percent slope. On the available site, fill was needed to obtain a 6 percent slope. The site had 3 to 12 inches of soil over a conglomerate rock and soil was added to the plot until the minimum soil depth was 12 inches; this raised the height of fill at the toe to about four feet. The soil was the same clay loam that was used in the pond dikes. A ditch was placed on the upper ends of the plots to divert rainfall runoff. The total area prepared was 100 ft x 115 ft, which was divided with 8-inch aluminum garden stripping into three 33 ft x 115 ft plots. Additional stripping was buried to a depth of four inches and placed around each plot to prevent wastewater surface flow from exiting except at the outlet structure. The aluminum stripping was connected to a concrete outlet structure and discharge pipe. Water meters were attached to the pipe for purposes of flow measurements; however, the available ten feet of head was insufficient to operate the meters. The flow measuring system was redesigned using a calibrated tipping bucket and counter arrangement.

The revolving irrigation gun normally used to spray wastes could not be used on these small plots. Instead, a revolving boom with a nozzle attached to one end was installed. The radius of the spray pattern was adjusted to remain within the 33-foot width. This arrangement allowed an even distribution of flow across the plot. Nozzles had a 1/8 inch opening and produced a fan-type spray.

The piping and valve arrangement was designed to allow wastewater to be taken from any one of the three pond effluents to be put on the plots. The motor-operated valves and pumps were actuated by automatic timers. The pumps were small impeller pumps designed for constant flow. The flow per unit of time for each plot was measured by catching the nozzle discharge in a container. Hydraulic loading was varied by the length of spray application. Ordinary household electric clocks were attached to the timers to integrate the amount of time wastewater was applied on each plot. Hand valves and pressure gauges were also installed to control the rate of flow.

The plots were sprigged with native bermuda grass which was chosen because of its ability to make a deep mat to provide a surface for bacteria growth. Since beef cattle and horses were placed in the surrounding pasture, an electric fence was installed around three plots to protect the grass and the smoothly sloped surface.

CONSTRUCTION

To determine construction costs, three competitive bids were obtained. Detailed drawings, specifications, contract documents and bid proposal were prepared for bidding purposes. Mr. W. E. Reeves, owner of the packinghouse, submitted the low bid of $21,400 which was less than the engineering estimate.

The use of packinghouse personnel resulted in minor delays in construction but minimized cash outlays. Construction of facilities shown in Figure 1 was mainly accomplished by three maintenance personnel at the packinghouse under the direction of the owner. Two others aided in operating dump trucks, front-end loader, and bulldozers during the earth moving phases of construction. Other part-time manpower consisted of a survey party and a supervisory engineer. No other manpower was required except that used by the electric company to relocate a power pole and to install service to the project.

The major equipment used on construction of the facilities consisted of two bulldozers (a D8 and a D6), one 16-yard Euclid earthmover, three dump trucks (1-12 yard and 2-6 yard), one backhoe, one front-end loader, one pickup truck, two air compressors, and a 1/2 sack concrete mixer. The owner purchased the Euclid earthmover and a D8 bulldozer for the construction. He leased air compressors and bulldozers when his were inoperable. The other equipment was already the property of the owner.

The major materials purchased were soil (a silty clay loam), vitrified clay sewer pipe, steel pipe for drains, cement, gravel and sand for concrete, form lumber, dynamite, an underground electrical cable, a sludge recirculation pump, a Parshall flume, and flow sampling and recording devices.

Construction was begun in December of 1970 and required four months to complete the pipelines, manholes, and three ponds. The anaerobic pond and sewer were completed first and waste turned into the pond on February 1, 1971. The transitional and stabilization ponds were completed next and received waste on April 15, 1971. The fence around the anaerobic pond, pilot irrigation plots, and auxiliary equipment were then installed. The last construction item was sprigging of the dikes with bermuda grass which was delayed until just prior to the 1972 growing season.

For small-packers who are considering construction of a treatment system, the detailed sequence of events was: (1) Move in the equipment, clear the site, and stockpile the organic topsoil for later use; (2) Excavate site for the anaerobic pond and installation of pond drain; (3) Construct dike on anaerobic pond; (4) Construct sewer pipeline and manholes; (5) Construct inlet and outlet structures to anaerobic pond; (6) Construct intake structures and housing for pumps; (7) Purchase pumping equipment; (8) Install pumping equipment and power source; (9) Excavate site for aerobic ponds (removal of rock by blasting was necessary) and install pond drains; (10) Construct aerobic pond dikes; (11) Construct inlet and outlet structures in aerobic ponds; (12) Install flow sampling and measuring devices and power source; (13) Clean up area and shape dikes and establish grass cover; (14) Install stock-tight fences and warning signs; and, (15) Shape the access road to the treatment system.

EVALUATION OF TREATMENT PROCESSES

General Procedure

Sampling is the most crucial part of any evaluation and considerable effort was made to obtain the best samples possible within the limitation of personnel and funds. Samples were taken on a weekly basis of the influent and effluent streams to each treatment process. Automatic composited samples were taken on all streams except the three effluents from the spray runoff irrigation plots. Experience with this process on other investigations has shown that grab samples of the effluent are satisfactory.

The automatic composite sampler used on the raw waste stream was a Model HG-4 by Sanford Products Corp which contains a dip-type mechanism. The automatic composite samplers used on the effluent streams from the anaerobic, transitional and stabilization ponds were Porta-Positer Samplers, Model U, by Nappe Corporation which contained an impeller pump and a sample splitting valve.

The samplers were connected to a time clock which activated each sampler during the normal slaughtering and processing period of the day. The samplers were set to take a sample three times per hour from 1 p.m. to 5 p.m. on Wednesdays and from 7 a.m. to noon on Thursdays when wastewater flow occurred. Samples were composited in a plastic container located in a refrigerator kept at 4° C.

The Biochemical Oxygen Demand (BOD) and Suspended Solids (TSS) analyses were initiated the same day the sample was collected since these two tests are sensitive to sample storage. Samples were stored at 4° C, and other analyses done during the week were Total Organic Carbon (TOC), Total Phosphate (T-P), Total Kjeldahl Nitrogen (TKN), Nitrate (NO_3-N), Nitrites (NO_2-N), Ammonia (NH_3-N), Total Solids (TS), Total Volatile Solids (TVS), and Chemical Oxygen Demand (COD). Temperatures of the waste streams were taken when the sample was collected. Occasionally, analyses were run to determine oil and grease, chloride and total alkalinity. Total Kjeldahl Nitrogen was analyzed according to Technicon Industrial Methods 30-69A. All other analyses were made in accord with FWPCA Methods for Chemical Analyses of Water and Wastes, November, 1969. Duplicate samples and unknown reference samples were run occasionally to determine accuracy and precision of the analytical results.

Anaerobic Pond

Raw waste was turned into the anaerobic pond in February 1971. Sampling of the influent and effluent was begun on March 11, 1971. Composite samples were first taken on the influent on May 6 and on the effluent on June 10, when the automatic sampler arrived from the manufacturer.

The collected data was placed on computer cards to enable machine tabulation and printout. Programs were prepared to produce machine plotted graphs showing concentration versus time for both the influent and effluent and percent removal versus time. Plotting of BOD_5 and TSS removals (Figure 4) showed stable conditions were obtained by July 15, 1972, 120 days after sampling was initiated. Thus, some five months or ten displacement periods were necessary to obtain stable conditions in the anaerobic pond. Concentration of BOD_5 in the raw waste continued to be highly variable throughout the study period but the anaerobic effluent dropped from levels over 2000 mg/l to values around 100 mg/l after July 15, 1971.

The evaluation period for the anaerobic period was nine months beginning July 15, 1971 and ending on April 20, 1972. During this period, the organic loading averaged 12 lb $BOD_5/1000\ ft^3$ and the detention averaged 11 days.

The significant changes in the anaerobic pond were in concentration of BOD, COD, TS, TVS, TSS, NH_3-N, and TOC with limited change noted in NO_2-N, NO_3-N, TKN, T-P, and Temperature. A table of the common statistical values of the analytical data is in Appendix A. Percent Removal of Oxygen Demand and Solids are shown in Table 3.

Table 3. Removal Efficiencies in Anaerobic Pond

	Oxygen Demand			Solids		
Item:	BOD_5	COD	TOC	TSS	TVS	TS
% Removal:	92	87	80	84	77	43

The consistence of the effluent (Anaerobic Effluent) concentration and variability of the influent (Raw Waste) concentration for BOD_5, COD, TSS and NH_3-N can be seen in Figure 5. These frequency vs. concentration graphs display the reliability of the anaerobic pond for treatment of a meat-packing waste.

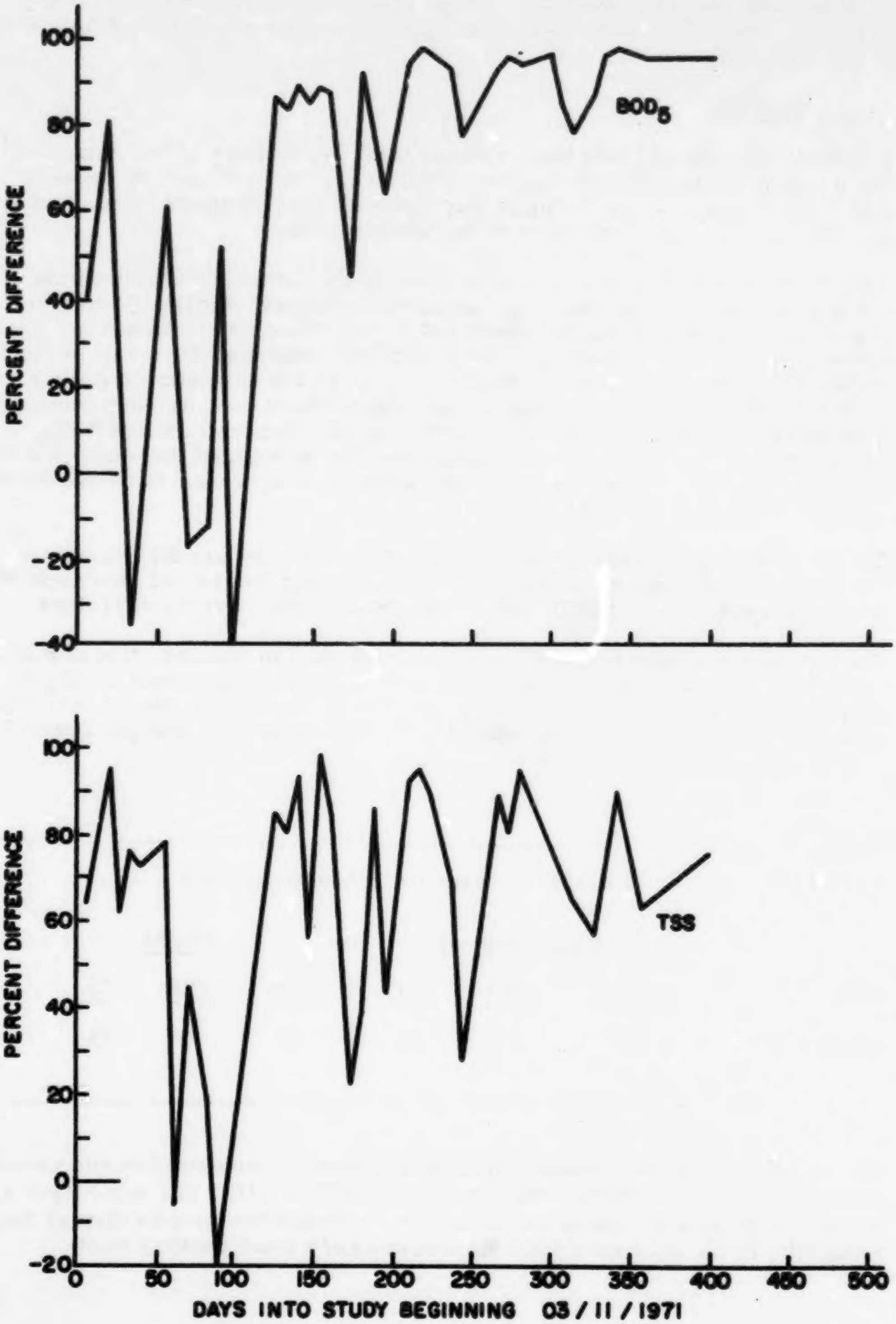


FIGURE 4 - ANAEROBIC POND REMOVALS

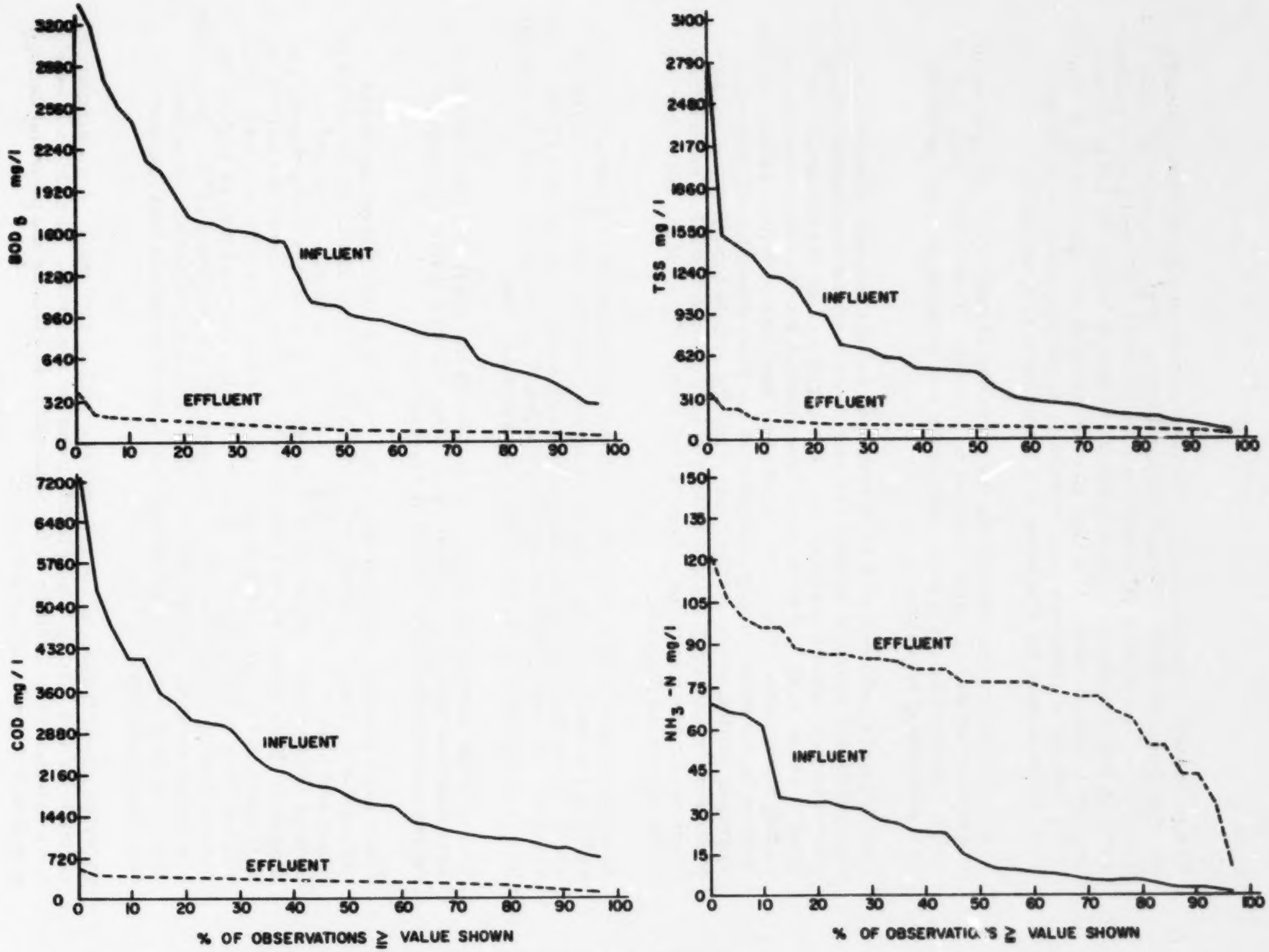


FIGURE 5 - ANAEROBIC POND - FREQUENCY VS. CONCENTRATION

The most common parameters used in determining municipal sewer rates for meat-packers are BOD, TSS and Oil and Grease. Figure 5 shows the BOD and TSS will be below 200 mg/l except on rare occasion. Oil and grease analyses made on the effluent show the concentration is well below the 100 mg/l level used by municipalities. The high percent removal and consistency of effluent concentration of anaerobic pond results in an effluent which would meet common limitations for discharge to a municipal treatment plant.

Two limitations of the process are the reduction of sulfate to hydrogen sulfite and the reduction of organic nitrogen to ammonia. The sulfate comes from the water supply while the organic nitrogen comes from the protein lost in the meat processing operation.

Discharge of an effluent with high hydrogen sulfide concentrations to a municipal system will result in damage to concrete sewers and structures unless precautionary devices are installed. Hydrogen sulfide is responsible for the smell of rotten eggs and even a low concentration has an offensive odor, resulting in nuisance complaints. At several locations with high sulfate concentrations in the water supply, the process has been discontinued because of hydrogen sulfide odors. At the study site, the sulfate concentration in the water supply was 4 mg/l and a hydrogen sulfide odor could not be detected. Other septic odors could only be detected within 50 feet of the anaerobic pond in the downwind direction.

Ammonia is toxic to fish and several states have restricted its concentration in receiving waters. The increase in ammonia (NH_3-N) is displayed in Figure 5, which shows that most of the effluent concentrations were between 65 mg/l and 85 mg/l. The conversion of organic nitrogen to ammonia increases the concentration of ammonia threefold through the anaerobic pond.

Several times during the study, the raw waste and anaerobic pond effluents were analyzed for oil and grease, chlorides and bicarbonate alkalinity to determine magnitude and change in concentrations.

The oil and grease concentrations in the raw waste and effluent averaged 514 mg/l and 16 mg/l, respectively, which shows limited loss in the packinghouse and high reduction in the anaerobic pond. A grease cover did not form on the anaerobic pond which indicates the grease was being digested in the pond. Some consideration was given to pouring grease on the surface of the lagoon and covering with straw to form a cover to reduce heat loss. This was not done and temperature reduction through the pond was as high as 60 percent during part of the winter dropping to values around 10° C. Only minor changes in removal efficiencies were noted during this period. In a colder climate there are greater advantages for a cover to reduce heat loss and maintain biological activities (13).

Chloride concentration in the raw waste averaged 1500 mg/l. A packinghouse normally adds 1,000 mg/l of chloride in use of the water. The chloride levels were determined in addition to the total solids to evaluate the potential damage to soil and crops by spray irrigation.

The alkalinity was determined as a check on volatile acids in the anaerobic pond. Alkalinity concentrations in the raw waste and effluent averaged 300 mg/l and 700 mg/l, respectively. Only bicarbonate alkalinity was present. McCarthy (14) has shown that the 85 percent of the volatile acid alkalinity is measured by titration of bicarbonate alkalinity. The volatile acids are capable of exhibiting alkalinity because at neutral pH values the acids are ionized and are in the form of acetates, propionates, etc. When titrating with acid, the hydrogen ions react with the salt ion registering as alkalinity. The magnitude of alkalinity in the effluent and the change through the pond show the volatile acids production was in control and that methane fermentation was not exhibited.

Sludge Recirculation

The sludge recirculating pump was installed and started into operation in March 1971; however, clogging was a continual problem. Clogging was mainly caused by hair jamming in the piping from the 1 1/2 discharge port. The flow delivered to manhole No. 5 by pump and motor was measured at 40 gpm. Several hours of maintenance were needed weekly and occasionally daily to unclog the pump.

After the anaerobic pond had stabilized and removal had reached high levels, the pump was not operated for two months (July and August). The pump was then turned on and operated most weeks in September and October. A concerted effort to maintain sludge recirculation was successful for two months (November and December). In January, February, and part of March, pump operations were unsuccessful four out of ten weeks. Recirculation efforts were abandoned in March because of maintenance requirements.

Temperature, BOD_5, COD, TVS, TSS and NH_3 data on the anaerobic effluent were grouped according to operation or non-operation periods of the recirculating pump. Hypothesis tests for difference of mean concentrations showed a significant difference at a probability (p) of 0.90 in all parameters except NH_3 between the two periods. The removal efficiencies, during the pump-off period (July-August) and the pump-on period (November-December), are shown in Table 4 for the significantly different parameters.

Table 4. Removal Efficiencies for Sludge Recirculation

	BOD_5	COD	TVS	TSS
Recirculating Pump Off	85	83	69	83
Recirculating Pump On	95	87	78	89

The anaerobic pond produced a poorer effluent without recirculation even under more favorable summer temperatures than with recirculation during fall weather conditions. The mixing and recirculation resulted in a greater removal efficiency and should be considered for medium or large packing-houses. However, for the small plants the recirculation pump is impractical because of the amount of required maintenance.

Transitional Pond

The layout of the transitional pond can be seen in Figure 1 and the area, volume, and inlet and outlet details are described in the design section. The liquid depth varies from 7 1/2 feet at the inlet to 3 feet at the outlet.

The discharge from the anaerobic pond was turned into the transitional (second) pond on April 15, 1971. In May, over half the volume and 90 percent of the surface area of the transitional pond was being used. The pond was filled by September 1971. Though data collection was begun early, evaluation of the process is based on data collected from September through April, a 6.5 month period. During this period, the pond maintained a light gray to green color with dissolved oxygen near saturation on the surface and at the outlet; thus, the transition from an anaerobic to aerobic system was accomplished. The pond overturned once during the period of warming air temperatures and the color changed to a darker gray on the surface; however, prior to collection of the weekly sample, conditions returned to normal. On one occasion the outlet pipe was plugged by soil which had eroded into the inlet. An extension of the pipe to move the inlet a foot from the dike prevented reoccurrence.

The organic loading averaged 52 lb BOD_5/acre/day for the five operating days per week. The displacement period (theoretical detention time) was 32 days. The significant changes in the transitional pond were in concentrations of BOD_5, COD and TSS. A table of the common statistical values of the analytical data is shown in Appendix A. The percent removal of oxygen demand, solids and nitrogen is shown in Table 5. There was little change noted in the T-P, NO_2-N, NO_3-N, and total TS.

Table 5. Removal Efficiencies in Transitional Pond

	Oxygen Demand		Solids		Nitrogen	
	BOD_5	COD	TVS	TSS	TKN	NH_3-N
Removal %	53	32	15	25	16	13

Comparison plotting of concentration data and removal efficiencies versus time provided little information even though several time lags between influent and effluent were used. The large variability in differential concentrations and removal efficiencies, based on individual values, was due to the limited sampling and large detention period. More meaningful displays of influent and effluent concentration are shown in Figure 6. These curves show the frequency of concentration and the change in concentration through the process. The process is most dependable in reducing the oxygen demand as measured by BOD_5 or COD. The TSS and NH_3-N curves show definite removal but of limited magnitude. The magnitude of effluent concentrations is what can be expected from the many meat-packing lagoon treatment systems which are similar in design.

Stabilization Pond

The area, volume, layout and details of design of the pond are described in the design section. The liquid depth ranges from 7 1/2 to 3 feet. With a minimum water depth of three feet, the displacement period (theoretical detention time) is 90 days. This can be increased or decreased 18 days by changing the outlet weir level one foot. The stabilization pond began receiving waste in late May 1971 and first discharged in September 1971. The pond color is light green due to algae and on several occasions, the wind has formed an algae mat along the shoreline. The baffle on outlet structure prevented these mats from being discharged. The pond has been aerobic and contains numerous frogs and turtles. Water from the pond has been used on three occasions to irrigate surrounding bermuda pasture. These grasses were later harvested by putting 17 head of cattle on the pasture.

The evaluation of the process was based on data collected from September through April, a 6.5 month period. The organic loading averaged 8.5 pounds per acre per day for the five operating days a week. The significant changes in the stabilization pond were in the concentrations of NH_3-N and TKN which were 73 and 66 percent, respectively. There was no change in BOD_5 concentration but COD increased by 20 percent. The concentration of TVS did not change, but TSS increased 25 percent. Cumulative frequency verus concentration graphs are displayed in Figure 7 for BOD, COD, NH_3-N and TSS. The decrease in ammonia (Figure 7) is not accounted for by an increase by a nitrate or nitrite. A summary of standard statistical parameters on the analytical data collected is presented in Appendix A.

The stabilization pond was of minor benefit in treatment. The production of algae in the pond apparently increased the COD and the total suspended solids. Outside of ammonia reduction, the major benefit of the pond was one of water storage for use during the irrigation season. At maximum water level, there is 1,670,000 gallons' storage capacity which would allow no discharge during the non-growing season. By careful management of the storage volume the annual wastewater flow of 10.5 acre feet could be pumped to irrigate part of the 20 acres in the surrounding pasture during the 224-day growing season.

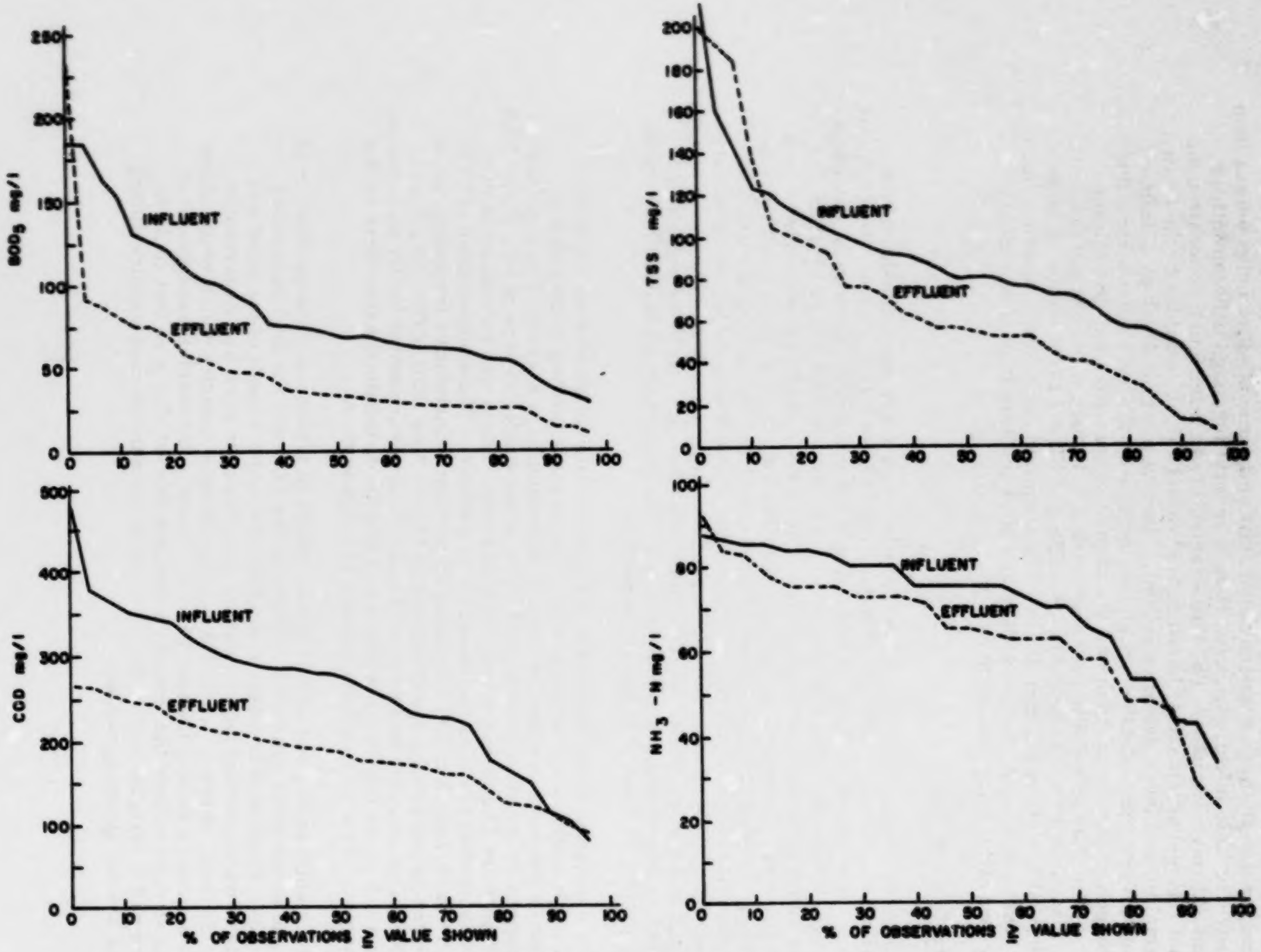


FIGURE 6 - TRANSITIONAL POND-FREQUENCY VS. CONCENTRATION

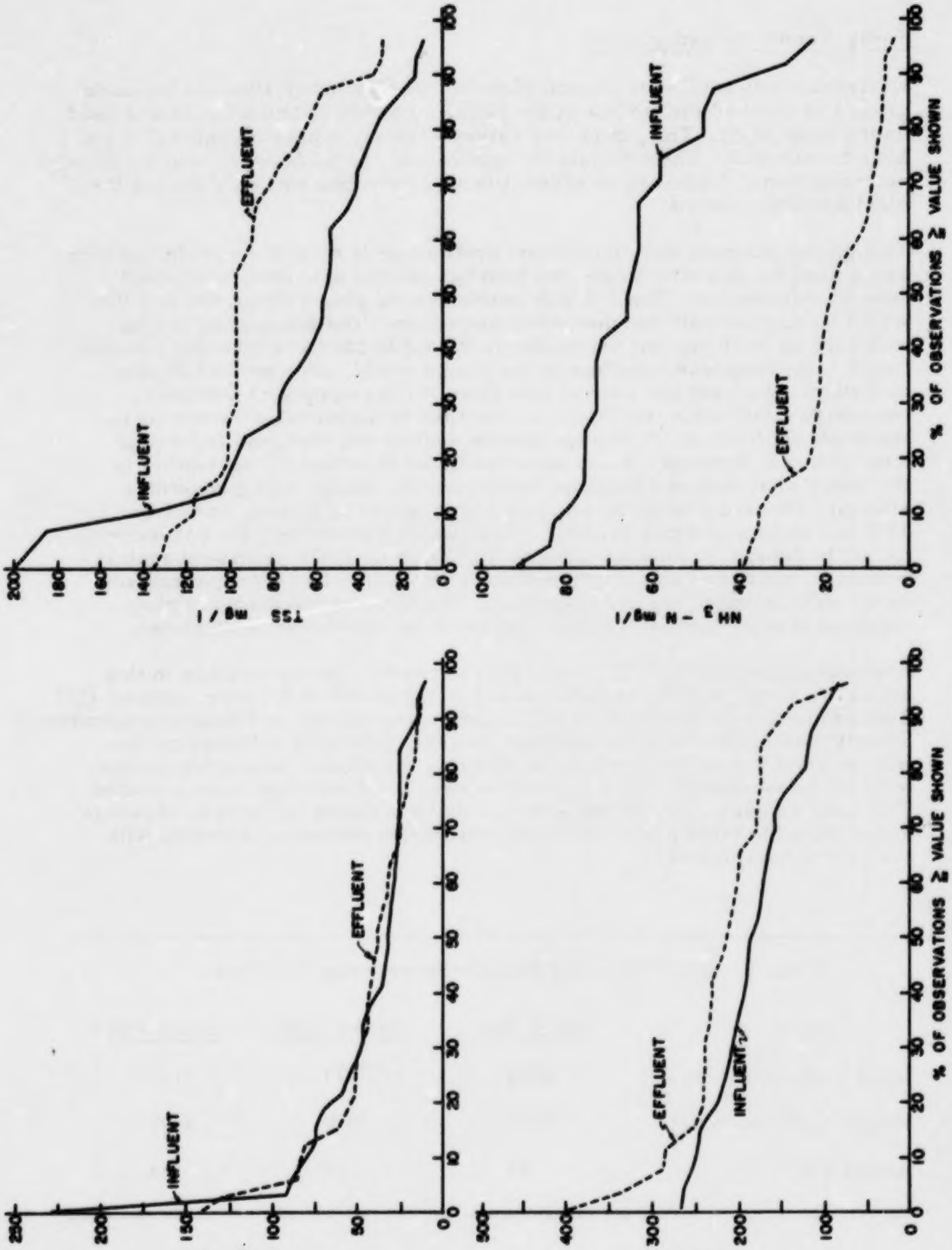


FIGURE 7 - STABILIZATION POND - FREQUENCY VS. CONCENTRATION

Spray Runoff Irrigation Plots

Wastewater was applied to the soil plots in mid-September after the bermuda grass had covered the surface of the plots. Anaerobic pond effluent was used on the three plots. The pumps and valves were set to provide equal flow per hour to each plot. The schedule for application was 5 1/2 days, Monday through Saturday noon. To insure an effluent flow, application was only during the plant operation period.

Though the pumping and distribution system copies a similar pilot installation being used for domestic waste, the first two months of operations showed several deficiencies. The 1/8 inch nozzles would plug with grease and flow would be stopped until the next daily inspection. The integrating clocks indicated up to 20 percent variability in the application cycle between weeks. Finally, the neoprene impellers in the pumps would, after several days of operation, take a set and deliver less flow. These equipment problems, common to small-scale test facilities, resulted in undesirable variations in the waste application. A new application system was designed and equipment ordered; however, it was more beneficial to accept the variability in the installed system and continue the six months' study, using anaerobic effluent. Process evaluation was based on a period beginning on October 7, 1971 and ending on April 20, 1972. Application was stopped for a three-week period in February, because maintaining the small-scale equipment against freezing conditions was not warranted. The common statistical parameters on the data collected are in Appendix A. The data showed the three plots receivsd nearly identical loadings and could be considered replications.

Previous experience with full-scale spray runoff irrigation systems in this area have shown that the runoff consists of 49 percent of the water applied (15). The loss in flow is attributed to infiltration, evaporation, and evapotranspiration. Twenty measurements of the cumulative weekly flow were collected on the influent, but due to the time loss in changing the effluent measuring device, only ten measurements of the cumulative weekly effluent flow were collected. The mean values in gallons per acre per day are shown in Table 6. Average runoff from the three plots was 56 percent, which compares favorably with the previous experience.

Table 6. Application and Runoff--Spray Irrigation Plots

Item	North Plot	Center Plot	South Plot
Input (gal./acre/day)	8832	7579	8169
Runoff (gal./acre/day)	5177	4070	4408
Runoff (%)	59	54	54

The hydraulic loading on the three plots averaged 8200 gallons per acre per day. The significant changes on the plots were in concentrations of BOD$_5$, COD, TSS, NH$_3$-N, and TKN. The percent removals of oxygen demand, nitrogen, and phosphorus concentrations are shown in Table 7. The change of phosphorus concentration was considerably less than the goal of 80 percent. A different operational scheme will be incorporated in subsequent investigation to increase phosphorus removal. Figure 8 shows the frequency of occurrence versus concentrations and the change in concentrations through the process for BOD$_5$, COD, TSS, and NH$_3$-N. The three effluent curves are shown on each figure along with the common influent curve.

Table 7. Concentration Reduction in Spray Irrigation Runoff (%)

Plots	Oxygen Demand		Solids	Nitrogen		Phosphorus
	BOD	COD	TSS	NH$_3$-N	TKN	T-P
North	74	57	65	72	72	17
Center	76	54	75	79	77	21
South	66	50	70	67	59	14

Removal efficiencies based only on concentrations are misleading in spray runoff irrigation systems because 44 percent of the wastewater applied was lost. Removal of the pollutants by spray runoff irrigation process needs to be expressed in terms of pounds in the point source discharge. The loadings and discharge of pollutants on the north, center, and south plots were nearly identical loadings and may be considered replications. The small variation in discharge values between plots could be expected from the curves shown in Figure 8. Overall discharge, loading and removal values for the three plots are present in Table 8. The anaerobic lagoon removed 80 percent of the organic carbon and the waste applied to the irrigation plot was lower in carbon than the carbon: nitrogen: phosphorus ratio of 100: 20: 1, considered ideal for bacterial cell production.

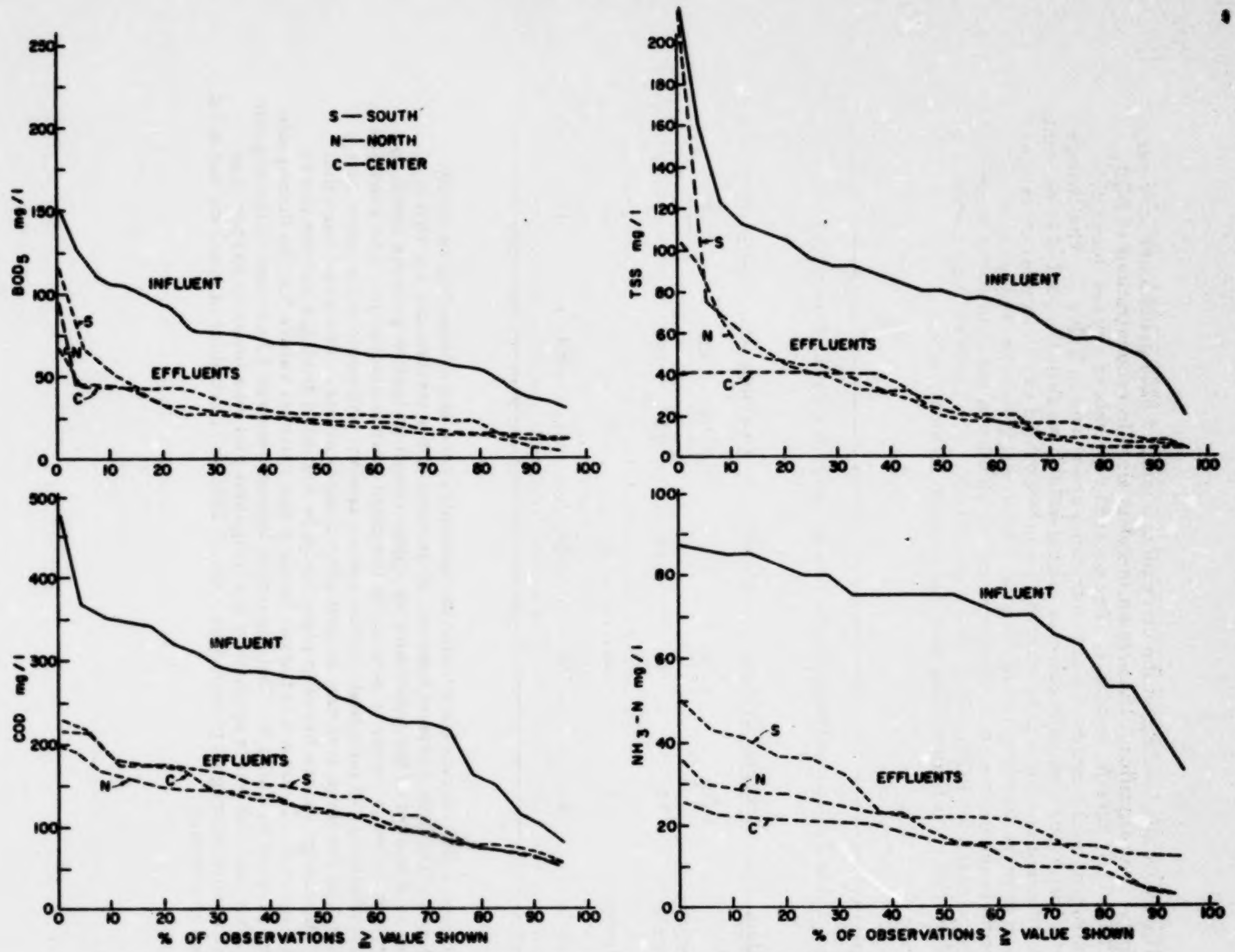


FIGURE 8 - SPRAY RUNOFF IRRIGATION PLOTS-FREQUENCY VS. CONCENTRATION

Table 8. Loading, Discharge and Removals--Spray Irrigation Plots

Items	Loading (lb/acre/day)	Discharge (lb/acre/day)	Removal (%)
BOD_5	4.6	0.8	83
COD	16.9	5.1	70
TOC	5.4	0.8	85
NH_3-N	4.9	0.8	84
P	1.1	0.4	64

COSTS

The total capital cost for construction of the three lagoons, pipelines and other appurtenances, including recirculating sludge facilities, was $21,400. Construction bids were received with prices on 28 specific items from three contractors. Eliminating the items necessary to recirculate sludge would have reduced the construction cost to $20,000. Land costs are not included because of the wide variance between locations. The cost per gallon of capacity is shown in Table 9.

Amortization of the capital expenditures are at 7 percent for 20 years. The shorter replacement period for the recirculating pump was accounted for in the annual repair parts for the pump which amounted to 20 percent of the cost of installing the recirculating sludge system. Annual operating and maintenance salaries were based on the owner's estimate of 8 to 10 man hours per week expended during the second year when the investigation was inactive. These costs included four mowings during the growing season and daily inspection and occasional repair of the system. The electric power costs were determined by the meter readings when the pump was in operation and adjusted to an annual basis. Eleven hundred kilowatt hours per month of power was used by the pump.

The monitoring costs were based on the suggested limits in the effluent guidance and the monthly analyses requested by the state. The cost of monitoring a discharge is dependent upon analyses performed, number of samples, and the means of samples collected. The least expensive valid means of monitoring a discharge for a small packer, if acceptable to the control agency, would be: (1) a collection of an automatic composited sample of a day's flow and a grab sample in a special sterile container; (2) shipment of the two samples in an iced container for analyses of BOD_5, SS, oil and grease, and fecal coliforms within 24 hours of collection by a contract laboratory; (3) analyses by the packer of pH and settleable solids on a grab sample; and, (4) measurement of the sampled discharge by a totalizing flow meter. Such monitoring would cost about $100 for each set of data.

The total treatment costs per lb of BOD_5 and COD applied are shown in Table 9.

Table 9. Treatment Costs for Anaerobic-Aerobic Ponds

Items	With Recirculating Sludge	Without Recirculating Sludge
Total Capital Costs	$21,400	$20,000
Construction Cost (at 17,800 gpd)	$1.20/gpd Capacity	$1.12/gpd Capacity
Amortized Capital Cost (7% - 20 years)	$ 2,020	$ 1,888
Annual Repair Parts	280	---
Annual Operating and Maintenance Salary	1,200	960
Annual Electric Power Cost	360	---
Annual Monitoring Cost	1,200	1,200
Total Annual Costs	$ 5,060	$ 4,048
Treatment Costs		
(50,440 lb BOD_5/year)	$0.10/lb BOD_5 Applied	$0.08/lb BOD_5 Applied
(81,500 lb COD/year)	$0.06/lb COD Applied	$0.05/lb COD Applied

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The estimated monitoring costs were $0.024 per lb of BOD_5 applied or 30 percent of the annual treatment cost without recirculating sludge. However, proposed EPA guidelines for state programs only require self-monitoring of discharges that average over 50,000 gallons per day. If these guidelines are adopted, many small meat-packers will not be faced with monitoring costs and the total cost for the system without sludge recirculation would be $0.056 per lb BOD_5 applied.

DISCUSSIONS

Treatment System Selection

The objectives of this project were to develop and demonstrate treatment systems to meet the needs of the meat industry, especially the small meat-packer. In this first phase of the investigation, two objectives were numerically quantified. These were: (1) demonstrate an anaerobic-aerobic lagoon system obtaining greater than 95 percent BOD removal producing an effluent of less than 50 mg/l, and (2) to develop and demonstrate a spray runoff irrigation system removing 80 percent of the nitrogen and phosphorus in the wastewater. Other objectives involving an all aerobic system with an aerated lagoon and spray runoff irrigation are to be studied in the second phase of this project.

The combination of treatment processes evaluated in Phase I gives four treatment systems. The performance of these four systems, in terms of removal efficiencies and effluent concentrations of oxygen demand, solids, nitrogen and phosphorus, are presented in Table 10. The removal efficiencies for the anaerobic pond with spray runoff irrigation are based on pounds which recognizes the water volume loss due to evaporation and infiltration. The total land requirements in Table 10 are those needed for the dikes and all appurtenances to handle the total flow in each system.

Table 10. Performance of Treatment Systems

Items	Anaerobic Pond	Anaerobic and Transitional Ponds	Anaerobic and Transitional and Stabilization Ponds	Anaerobic Pond and Spray Runoff Irrigation*
BOD_5 Removal (%)	92	96	96	99
BOD_5 Effl. (mg/l)	102	47	44	28
COD Removal (%)	87	92	90	97
COD Effl. (mg/l)	273	182	217	126
TSS Removal (%)	84	88	85	97
TSS Effl. (mg/l)	94	71	88	28
TVS Removal (%)	77	81	81	89
TVS Effl. (mg/l)	309	262	252	254
NH_3-N Removal (%)	-252	-204	14	47
NH_3-N Effl. (mg/l)	74	64	18	20
TKN Removal (%)	2	18	72	84
TKN Effl. (mg/l)	97	81	28	29
PO_4-P Removal	-18	-18	8	44
PO_4-P Effl. (mg/l)	13	13	9	11
Total Land Requirement (Acre)	.5	1.1	2.5	3.3

*Removals based on a 44% water loss due to evaporation and infiltration.

Though the anaerobic pond accounted for most of the removal of oxygen demand, it did not, by itself, meet the BOD_5 objective of 50 mg/l; however, in combination with the transitional pond or with the transitional and stabilization pond this objective was obtained. The combined anaerobic and transitional ponds meet this objective with minimum land requirement and capital cost. The stabilization pond did not reduce the oxygen demand and increased the suspended solids. Its value is limited to removal of nitrogen, especially ammonia nitrogen and to storage and controlled release of the effluent.

In regard to the second objective of 80 percent removal of phosphorus and nitrogen, the anaerobic-transitional-stabilization ponds and the anaerobic pond-spray runoff irrigation systems accomplished 72 and 84 percent nitrogen removal, respectively. None of the systems accomplished the desired phosphorus removal. In the second phase of this project, application of wastewaters to the irrigation plots will be altered to duplicate schemes resulting in phosphorus removal from other food processing wastewaters.

After the project had been designed and the treatment systems constructed and operational, effluent guideline development was initiated by the U.S. Environmental Protection Agency and the Oklahoma Water Resources Board. The possible federal effluent limitations are discussed under the section "National Effluent Limitations." The Oklahoma Water Resources Board established guidelines for effluent quality for discharge into intermittent streams which are defined in terms of maximum effluent concentrations in mg/l. The state limitations (Technical Release 1002) that are relevant to meat-packing wastewaters are 2.5 mg/l NH_3-N, 1.0 mg/l P, 40 mg/l BOD_5, 45 mg/l TSS, 15 mg/l oil and grease, and a requirement that the effluent shall not cause the DO to be depressed below 4 mg/l in the receiving water.

Because of the limitations of NH_3-N and PO_4-P, none of the four systems meet these effluent discharge guidelines. The anaerobic pond with spray runoff irrigation meets the other limitations. This system with different application techniques on the spray runoff irrigation may be able to meet the ammonia and phosphorus limits. In the Phase II studies, the aerated pond as an extended aeration process has the potential of meeting the ammonia and phosphorus limits as other extended aeration plants treating meat-packing wastes have obtained these limits. To obtain these NH_3-N or P limits by either spray runoff irrigation or extended aeration requires considerable monitoring and operation experience which is not likely to be available to small meat-packers. The cost of such operation and monitoring would make additional capital expenditures more economical for the small packer.

At this small packinghouse, the available pasture makes practical land disposal to eliminate the discharge and the cost for monitoring or operating an extensive treatment system for NH_3-N or P removal. The stabilization pond will allow storage of the wastewaters during the non-growing season. During the growing season, the wastewaters could be beneficially used to irrigate the adjacent pasture. Irrigation could be scheduled to meet plant requirements and prevent runoff. Besides the available storage, spray irrigation facilities would be required. These additional irrigation facilities were designed to apply 10.5 acre feet in 200 days on part of the 20-acre pasture. The estimated annual cost, including depreciation, power, repair and taxes, would be $600. This cost (half of that required for monitoring) may make land disposal more economical than discharge to the receiving water. However, these are the added on costs to already available storage facilities and land area. At this small packinghouse, the annual cost for storage facilities and irrigation facilities would be equivalent to the cost of monitoring a discharge. The uncertainty and big cost for other packers is the cost of land which can only be determined on an individual plant basis.

National Effluent Limitations

National effluent limitations are proposed to be based on units of pollutants per unit of product. In the meat industry, both raw wastewaters and treated discharges are often described in lb/1000 lb of LWK. During the study period, the W. E. Reeves Packinghouse's annual live weight kill was 10,700,000 pounds.

The average kill for the five killing days per week was 40,989 lb LWK/day with cattle plus calves averaging 33,133 lb, and hogs, 7,858 lb. This is equivalent to 36 head of beef and 36 head of hogs per day. On days that samples were collected, the average LWK was 40,850 pounds.

Four previous surveys of the meat industry have defined raw wastewater characteristics in terms of Live Weight Killed (16). In small plants and new plants such information is a common basis for design. A comparison of characteristics of raw wastewaters (Table 11) from the W. E. Reeves Packinghouse and recent survey data (1) from 11 slaughterhouses and 52 packinghouses shows the Reeves plant to agree more closely with a typical slaughterhouse than a packinghouse. The slaughterhouses and packinghouses in the survey were medium and large size plants and all practiced inedible rendering. The Reeves plant does produce lard, hams, bacon, sausage, weiners, lunchmeat, chili, etc., like most packinghouses. The reduced waste load may be attributable to the fact that there is no inedible rendering, and the blood and paunch contents are not disposed of in the sewer system.

Table 11. Comparison of Raw Wastewater Load/1000 lb LWK

(Mean Values)

Parameter	Reeves Packinghouse	Slaughterhouses	Packinghouses
Flow (gal)	435.	695.	1046.
BOD_5 (lb)	4.49	5.8	12.1
TSS (lb)	2.16	4.7	8.7
Grease (lb)	1.85	2.5	6.0
TKN (lb)	0.36	0.27	0.97
Cl^- (lb)	5.40	12.8	4.70
P (lb)	0.04	0.04	0.17

A comparison of BOD_5 and suspended solids on each process effluent with effluent limitations under consideration in July 1972 for slaughterhouses and packinghouses is in Table 12. These interim limits may be the basis for approval of discharge permits for large and medium meat-packers until national effluent limitations are established.

Table 12. Comparison of Treated Wastewater and Potential Discharge Limits

Treatment Systems	BOD_5 (#/1000#LWK)	TSS (#/1000#LWK)
Anaerobic Effluent	0.37	0.33
Transition Effluent	0.17	0.25
Stabilization Effluent	0.16	0.32
Irrigation Runoff*	0.06	0.06
Potential Effluent Limits "A"		
Slaughterhouses	0.17	0.23
Packinghouses	0.26	0.35
Potential Effluent Limits "B"		
Slaughterhouses	0.30	0.47
Packinghouses	0.61	0.87

*Based on 44% water loss due to evaporation and infiltration.

Potential effluent limits "B" represent the possible minimum acceptable effluent levels for the meat processing industry. Potential effluent limits "A" may be applicable for new plants installing pollution abatement equipment and existing plants now beginning abatement programs. The anaerobic pond in combination with the transitional or the irrigation plot meets the potential limitations in Table 12 for a packinghouse discharge. There are also potential limitations on settleable solids of 0.1 ml/l, on oil and grease 15 mg/l, on pH of between 6.0 and 8.5 and on fecal coliform counts of 1000/100 ml. The limited number of analyses made on these parameters indicated the discharges can meet the potential interim guidelines except in the case of fecal coliforms. Some fecal coliform counts in stabilization pond discharges meet the limit but not all. Disinfection may be necessary to meet this limitation.

Other parameters being considered before approval of a discharge permit are: toxic materials, ammonia, phosphate, dissolved solids, color and turbidity. Of these, ammonia is the most significant in the meat-packing wastewaters. Ammonia has also been included in the list of toxic materials and numerical limitations are expected to be set nationwide. Several states have already established effluent limits on NH_3-N of 2.0 to 2.5 mg/l. The average concentration in the effluent from the anaerobic pond, transitional pond, stabilization pond, and soil plots were 74, 64, 18, 20 mg/l, respectively. The magnitudes of these values in relation to state limits are such that different or additional treatment processes will be needed. Similar nationwide ammonia limits on effluent discharges will result in a major change in meat-packing waste treatment systems.

Receiving Streams

Wastewater from the W. E. Reeves Packinghouse is discharged into an unnamed stream six-tenths of a mile above its confluence with Sandy Creek. Below the point of discharge, this small stream meanders through two pastures and is used for stock watering. Sandy Creek is an intermittent stream discharging to the South Canadian River 12 miles below this confluence. Three miles above the mouth of Sandy Creek two mgd of treated municipal effluent are discharged via a tributary. Several sand and gravel pits and numerous oil and gas wells are located in the pasture lands bordering Sandy Creek. The creek is used for stock watering and municipal and industrial waste discharges.

After a period of three weeks with no precipitation, stream flow measurements were made on June 21, 1972. Flow in the unnamed creek below the discharge was 200 gpm and the flow in Sandy Creek below the confluence with the unnamed creek was 2,000 gpm. Later in the summer, on July 31, 1972, the unnamed creek had a flow of 140 gpm, but there was no flow in Sandy Creek. The flow in the unnamed creek is continuous because of a cooling water discharged from a local industry.

Four stream surveys were made from the point of the discharge on the unnamed stream to its confluence with Sandy Creek and from that confluence to one mile downstream on Sandy Creek. One summer and one winter survey were conducted prior to and following the initiation of the treatment system. These surveys were conducted to determine limnological changes in the streams due to treatment. Observations were made at eight stations on the unnamed creek and at four stations on Sandy Creek.

On June 10, 1970, the first stream survey was made. The unnamed stream is characterized by a rock bottom with sand and gravel deposits. Six orders of macroinvertebrates including damselfly and mayfly nymphs were collected above the packinghouse waste discharge. Green algae scums were sparsely attached to the rock and the dissolved oxygen (DO) concentration was at saturation. Downstream from the discharge the more sensitive nymphal insects were nonexistent. Sewage bacteria and sludge worms increased with increasing distance from the discharge. DO concentrations were below saturation with lowest concentration of 4 mg/l occurring in an eddy pool one-quarter of a mile below the discharge. Water temperatures varied from 25° to 26° C and DO from 4 to 8 mg/l.

Sandy Creek, above the confluence with the unnamed stream, was typified by clear water and clean gravel and sand without sludge banks. DO concentrations were at saturation. The shifting sand bottom is not conducive to biotic colonization, so these forms were not available for observation; but minnows and other fishes were observed.

Below the confluence with the unnamed stream, water in Sandy Creek was slightly milky and the gravel was blackened with organic sludge deposits. Between a quarter to a half a mile downstream from the confluence, waters in Sandy Creek were again clear and the gravel and sand were clean. Water temperatures in Sandy Creek varied from 27° to 30° C. DO concentrations varied from 6.8 to 12.3 mg/l, dropping from 8.0 mg/l 100 feet above the confluence to 6.8 mg/l 100 feet below the confluence. Minnows were observed all along Sandy Creek.

A second survey was made on January 12, 1971, the increased winter flows had altered the depositional characteristics of Sandy Creek but not those of the unnamed stream. At least 12 varieties of macroinvertebrates inhabited the small stream above the packinghouse discharge. These included dragonfly, midge, and blackfly larvae and the large population of first or second instar mayfly nymphs. The population below the wastewater discharge consisted primarily of a few red midge larvae and numbers of sludge worms. These organisms were found primarily in grain, cereal and animal scrap deposits on the lee side or bottom of the stream. Slimes of sewage bacteria were dense 50 to 100 feet below the discharge. Cladophora, which was sparse above the discharge, was dense 100 feet to 400 feet below the discharge. The color of the water and foam, which formed below the riffles, ranged from a bright claret near the discharge to a straw yellow at the confluence with Sandy Creek. Odors from the wastes were detectable 800 feet below the discharge. In the unnamed stream, the water temperature was 6° C and the DO ranged from 10.2 to 12.5 mg/l. The water temperature in Sandy Creek was 3° C and the DO ranged from 12.6 to 13.0 mg/l.

After the treatment facilities had been constructed, the third survey was made on July 8, 1971. The amount of silt and algae scum in the unnamed stream indicated there had not been a recent rainfall sufficient to scour the rocky bottom. There was little variation in the community structure of the biota in the stream in the vicinity of the discharge. In one eddy pool, about 50 feet downstream from the discharge, there was enough remaining organic material to cause significant variation in the benthic community. Sandy Creek had low flow and a silt covered bottom indicating a lengthy period of time since the last scouring flows. Bottom conditions did not show any change below the confluence of the unnamed stream. In the unnamed stream and in Sandy Creek, temperatures ranged from 25° to 26° C and dissolved oxygen ranged from 7.5 to 7.8 mg/l. Abundant minnow populations were observed at all stations.

The fourth survey was made on January 24, 1972, following a period when flows in the unnamed creek had been insufficient to scour the silt and biota from the substrate. A broad generic range of benthos was observed in the stream, with relatively few individuals representing each genera. In addition to the diverse macroinvertebrate population, there was a large amount of attached cladophora. A profuse algae population was present in the treated discharge from the packinghouse. The algal community was diverse with flagellated green species being the most abundant. The water temperature was 8.5° C and the DO was 6 mg/l in the unnamed creek.

The flow in Sandy Creek was above normal. Due to the unstable and shifting bottom, macroinvertebrate organisms were not present. The water temperature ranged from 7° to 7.5° C and the DO ranged from 11.5 to 12.2 mg/l.

Samples were collected for microbiological analyses on January 21, 1971, when untreated wastewaters were being discharged; and on June 21, 1972, when treated effluent was being discharged. The results are shown in Table 13. A reduction of 1 to 3 orders of magnitude in these organisms was measured. The largest change was in the number of organisms in the wastewater discharge.

Table 13. Microbiological Survey of Discharge and Receiving Stream

	Fecal Coliforms Per 100 ml		Fecal Streptococci Per 100 ml	
Station	Before	After	Before	After
25 ft above discharge	4.0×10^3	2.0×10^3	3.3×10^4	2.5×10^3
Wastewater discharge	6.2×10^5	1.1×10^2	9.5×10^6	1.9×10^3
50 ft below discharge	1.6×10^4	1.1×10^3	1.1×10^6	4.2×10^3
1/2 mile below discharge	6.0×10^3	3.0×10^2	2.2×10^5	2.0×10^3

As a result of the installation and operation of the treatment facilities at the W. E. Reeves Packinghouse, pollution was abated in a 0.6 mile reach of the unnamed stream and a 0.5 mile reach of Sandy Creek. Physical evidence of this was the elimination of excessive oxygen demand, disagreeable odors, and unsightly sludge banks, water color, and foam. Biological evidence included increased biotic diversity and the reduction in fecal coliforms and fecal streptococci.

ACKNOWLEDGMENT

This research project was the cooperative study by East Central State College, W. E. Reeves Packinghouse, and the Robert S. Kerr Environmental Research Laboratory. The project was supported in part by the Environmental Protection Agency under Project No. 12060 GPP.

Mr. Phil Wright and Mrs. Susan Stinnett, instructors in the Environmental Science Department, East Central State College, were responsible for the analytical chemistry undertaken by themselves and work-study students.

Mr. W. E. Reeves, owner of the packinghouse, along with plant maintenance and operating employees constructed the treatment system and performed the maintenance and operation.

Mr. R. Douglas Kreis, aquatic biologist, surveyed the receiving streams and reviewed that section of the report. Mr. S. C. Yin, microbiologist, made the coliform counts. Mr. Jim Kingery, mathematical statistician, developed the printout and plotting programs. Mr. Michael Cook, chemistry technician, did the special chemical analyses. Mr. Tom Redman, Mr. Montie Fraser, and Mr. Lowell Penrod, engineering technicians, did the surveying, drafting, inspection of the construction and maintenance of the monitoring equipment. Mrs. Josephine Leonard typed and assembled the manuscript. These individuals are on the Robert S. Kerr Environmental Research Laboratory staff.

This report has been reviewed by the Office of Research and Monitoring, Environmental Protection Agency, and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the Environmental Protection Agency, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

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Appendix A

COMMON STATISTICS ON DATA BASE

RAW WASTEWATER - 71/06/17 to 72/04/20

			Mean	Stan Dev	Maximum	Minimum
Parameter		No.	Median	Range	Beg Date	End Date
Temp	Cent	38	23.1315	3.3705	27.0000	14.0000
			24.0000	13.0000	71/06/17	72/04/20
BOD_5	mg/1	40	1247.8000	802.4431	3337.0000	265.0000
			988.5000	3072.0000	71/06/17	72/04/20
COD	mg/1	35	2159.9600	1497.8731	7170.0000	490.7000
			1691.0000	6679.3000	71/06/17	72/04/20
TS	mg/1	37	3404.7567	1184.5759	6371.0000	1257.0000
			3397.0000	5114.0000	71/06/17	72/04/13
TVS	mg/1	37	1350.0000	888.5936	4161.0000	420.0000
			1112.0000	3741.0000	71/06/17	72/04/13
TSS	mg/1	36	600.8611	590.1532	3012.0000	44.0000
			494.0000	2968.0000	71/06/17	72/04/13
NH_3-N	mg/1	33	20.9939	19.6946	68.0000	1.0000
			14.0000	67.0000	71/06/17	72/04/20
NO_2-N	mg/1	16	0.3150	0.3090	1.1000	0.0500
			0.1650	1.0500	71/09/16	72/04/13
NO_3-N	mg/1	15	3.1986	9.3872	37.0000	0.0600
			0.5000	36.9400	71/09/16	72/04/13
TKN	mg/1	35	99.3428	52.3144	260.0000	27.0000
			92.5000	233.0000	71/06/17	72/04/20
P	mg/1	32	11.3665	5.7244	28.8000	2.2000
			10.7600	26.6000	71/06/17	72/04/20
TOC	mg/1	22	500.3636	281.1258	1160.0000	112.0000
			480.0000	1048.0000	71/06/17	72/04/13
Hogs	#LWK/day	37	8000.	163.	9350.	4050.
			-	4300	71/06/17	72/04/20
Beef	#LWK/day	37	32850.	778.	39950.	22200.
			-	17750.	71/06/17	72/04/20
TOTAL	#LWK/day	37	40850.	772.	50650.	29600.
			-	21050.	71/06/17	72/04/20

ANAEROBIC EFFLUENT - 71/07/15 to 72/04/20

Parameter		No.	Mean Median	Stan Dev Range	Maximum Beg Date	Minimum End Date
Temp	Cent	38	16.8421	6.5120	26.0000	4.0000
			16.5000	22.0000	71/07/15	72/04/20
BOD_5	mg/l	39	102.1576	64.6678	370.0000	29.0000
			76.1000	341.0000	71/07/15	72/04/20
COD	mg/l	34	273.6764	88.8779	484.3000	77.1000
			281.7500	407.2000	71/07/15	72/04/20
TS	mg/l	36	1949.5555	290.0615	2482.0000	1528.0000
			1869.5000	954.0000	71/07/15	72/04/13
TVS	mg/l	36	309.0833	110.6013	543.0000	117.0000
			300.0000	426.0000	71/07/15	72/04/13
TSS	mg/l	36	93.9722	43.3342	226.0000	20.0000
			86.0000	206.0000	71/07/15	72/04/13
NH_3-N	mg/l	32	73.9187	21.7526	121.2000	9.2000
			75.0000	112.0000	71/07/15	72/04/20
NO_2-N	mg/l	17	0.6200	0.8315	2.3000	0.0000
			0.2500	2.3000	71/09/16	72/04/13
NO_3-N	mg/l	16	0.6093	1.0531	3.3000	0.0000
			0.1350	3.3000	71/09/16	72/04/13
TKN	mg/l	35	96.7514	13.2890	125.0000	70.0000
			96.0000	55.0000	71/07/15	72/04/20
P	mg/l	33	13.3836	4.2269	21.6000	2.6000
			13.9200	19.0000	71/07/15	72/04/20
TOC	mg/l	21	120.0714	78.3945	405.0000	25.0000
			80.0000	381.0000	71/07/29	72/04/13

TRANSITIONAL EFFLUENT - 71/09/02 to 72/04/20

Temp	Cent	30	11.4666	6.5323	23.0000	0.0000
			11.5000	23.0000	71/09/02	72/04/20
BOD_5	mg/l	32	47.5131	42.6526	247.0000	10.0000
			33.0000	237.0000	71/09/02	72/04/20
COD	mg/l	26	182.4538	50.7603	265.5000	82.6000
			185.1500	182.9000	71/09/16	72/04/20
TS	mg/l	29	1921.1034	247.5356	2392.0000	1612.0000
			1795.0000	780.0000	71/09/02	72/04/13
TVS	mg/l	29	262.5172	94.1763	527.0000	95.0000
			266.0000	432.0000	71/09/02	72/04/13
TSS	mg/l	29	70.5517	51.4389	200.0000	8.0000
			56.0000	192.0000	71/09/02	72/04/13
NH_3-N	mg/l	24	64.0541	16.5635	92.5000	22.5000
			65.0000	70.0000	71/09/02	72/04/20
NO_2-N	mg/l	16	0.2731	0.3935	1.6000	0.0000
			0.1000	1.6000	71/09/16	72/04/13
NO_3-N	mg/l	17	0.2447	0.3998	1.7100	0.0000
			0.1000	1.7100	71/09/16	72/04/13
TKN	mg/l	28	81.3035	12.2143	103.0000	46.0000
			82.2500	57.0000	71/09/02	72/04/20
P	mg/l	26	13.3350	3.5752	20.0000	3.2000
			13.9000	16.8000	71/09/02	72/04/20
TOC	mg/l	19	78.3947	42.8798	235.0000	30.0000
			72.5000	205.0000	71/09/16	72/04/13

STABILIZATION EFFLUENT - 71/09/02 to 72/04/20

			Mean	Stan Dev	Maximum	Minimum
Parameter		No.	Median	Range	Beg Date	End Date
Temp	Cent	33	10.7878	6.2836	21.0000	0.0000
			12.0000	21.0000	71/09/02	72/04/20
BOD_5	mg/1	33	44.5687	30.7925	144.0000	11.3000
			38.0000	132.7000	71/09/02	72/04/20
COD	mg/1	26	217.6730	63.0127	401.9000	74.3000
			214.4500	327.6000	71/09/16	72/04/20
TS	mg/1	31	1998.8064	249.3075	2450.0000	1311.0000
			1917.0000	1139.0000	71/09/02	72/04/13
TVS	mg/1	31	252.7419	91.1332	402.0000	101.0000
			240.0000	301.0000	71/09/02	72/04/13
TSS	mg/1	30	88.1000	27.3475	135.0000	28.0000
			96.0000	107.0000	71/09/02	72/04/13
NH_3-N	mg/1	27	17.6740	10.6033	38.5000	3.5000
			18.5000	35.0000	71/09/02	72/04/20
NO_2-N	mg/1	14	1.7764	3.0625	10.0000	0.0000
			0.5600	10.0000	71/10/14	72/04/13
NO_3-N	mg/1	16	4.6650	3.5168	11.0000	0.1000
			4.3000	10.9000	71/09/16	72/04/13
TKN	mg/1	28	27.7857	13.6796	51.0000	8.0000
			22.5000	43.0000	71/09/02	72/04/20
P	mg/1	26	9.1350	2.7552	15.2000	0.9800
			9.0400	14.2200	71/09/02	72/04/20
TOC	mg/1	19	70.4736	24.1600	115.0000	39.0000
			70.0000	76.0000	71/09/16	72/04/13

NORTH IRRIGATION RUNOFF - 71/10/07 to 72/04/20

Temp	Cent	16	10.3750	2.9183	15.0000	6.0000
			10.5000	9.0000	72/02/17	72/04/20
BOD_5	mg/1	28	26.8460	17.3059	99.0000	11.0000
			22.5000	88.0000	71/10/14	72/04/20
COD	mg/1	24	117.3499	38.5902	195.0000	53.6000
			119.5000	141.4000	71/10/21	72/04/20
TS	mg/1	26	1886.2692	306.0431	2338.0000	1065.0000
			1871.5000	1273.0000	71/10/07	72/04/20
TVS	mg/1	26	245.3076	93.9168	400.0000	81.0000
			268.0000	319.0000	71/10/07	72/04/20
TSS	mg/1	26	32.8076	25.1300	104.0000	4.0000
			28.0000	100.0000	71/10/07	72/04/20
NH_3-N	mg/1	19	20.4105	7.2446	36.5000	12.0000
			18.0000	24.5000	71/10/14	72/04/20
NO_2-N	mg/1	15	2.8999	2.9814	8.2000	0.0500
			1.3000	8.1500	71/10/14	72/04/13
NO_3-N	mg/1	12	9.9325	6.8374	24.0000	0.6200
			10.7000	23.3800	71/10/14	72/04/13
TKN	mg/1	22	26.1590	8.0332	42.0000	11.0000
			24.5000	31.0000	71/10/07	72/04/20
P	mg/1	21	11.0514	3.5141	16.8000	1.0000
			11.5600	15.8000	71/10/07	72/04/20
TOC	mg/1	16	55.4687	33.6894	125.0000	10.0000
			52.5000	115.0000	71/10/07	72/04/13

CENTER IRRIGATION RUNOFF - 71/10/07 to 72/04/20

			Mean	Stan Dev	Maximum	Minimum
Parameter		No.	Median	Range	Beg Date	End Date
Temp	Cent	7	9.7142	2.5634	13.0000	6.0000
			10.0000	7.0000	72/02/17	72/04/20
BOD_5	mg/l	21	24.4904	16.0034	72.0000	3.0000
			21.0000	69.0000	71/10/07	72/04/20
COD	mg/l	17	126.2411	49.2342	212.4000	53.6000
			117.2000	158.8000	71/10/21	72/04/20
TS	mg/l	18	1914.1666	370.6000	2638.0000	1084.0000
			1880.0000	1554.0000	71/10/07	72/03/30
TVS	mg/l	18	269.5555	100.7701	427.0000	18.0000
			277.0000	409.0000	71/10/07	72/03/30
TSS	mg/l	18	23.2777	14.2738	40.0000	4.0000
			22.0000	36.0000	71/10/07	72/03/30
NH_3-N	mg/l	14	15.1785	7.0126	25.5000	3.0000
			16.2500	22.5000	71/10/14	72/04/20
NO_2-N	mg/l	11	3.0136	2.3039	6.0000	0.3000
			2.6000	5.7000	71/10/14	72/01/20
NO_3-N	mg/l	7	15.1928	8.3876	28.6500	4.0000
			12.9000	24.6500	71/10/14	72/01/20
TKN	mg/l	18	21.6111	8.6476	37.5000	6.0000
			22.0000	31.5000	71/10/07	72/04/20
P	mg/l	16	10.4850	4.0444	18.9000	1.2000
			10.7200	17.7000	71/10/07	72/04/20
TOC	mg/l	11	58.1818	34.0787	110.0000	10.0000
			65.0000	100.0000	71/10/07	72/02/17

SOUTH IRRIGATION RUNOFF - 71/10/07 to 72/04/20

Temp	Cent	7	11.2857	2.7516	15.0000	7.0000
			12.0000	8.0000	72/02/17	72/04/20
BOD_5	mg/l	19	34.4247	24.5849	119.0000	11.0000
			26.2500	108.0000	71/10/14	72/04/20
COD	mg/l	19	135.8894	50.1131	230.1000	55.3000
			141.4000	174.8000	71/10/07	72/04/20
TS	mg/l	18	1966.6111	318.3406	2487.0000	1335.0000
			1967.5000	1152.0000	71/10/07	72/04/13
TVS	mg/l	18	247.6111	89.2103	365.0000	63.0000
			269.0000	302.0000	71/10/07	72/04/13
TSS	mg/l	18	28.0111	21.9314	75.2000	4.0000
			22.0000	71.2000	71/10/07	72/04/13
NH_3-N	mg/l	16	24.6062	14.1788	51.0000	2.5000
			21.5000	48.5000	71/10/07	72/04/20
NO_2-N	mg/l	14	2.6178	2.2287	5.6000	0.0500
			1.8000	5.5500	71/10/14	72/04/13
NO_3-N	mg/l	11	12.5218	6.5774	24.9000	2.4000
			10.6000	22.5000	71/10/14	72/04/13
TKN	mg/l	19	39.2368	20.9970	97.0000	2.8000
			37.5000	94.2000	71/10/07	72/04/20
P	mg/l	17	11.4700	3.9475	19.6800	3.2000
			12.0000	16.4800	71/10/07	72/04/20
TOC	mg/l	14	56.8214	36.8571	140.0000	10.0000
			57.5000	130.0000	71/10/07	72/04/13

LAND DISPOSAL OF POTATO STARCH PROCESSING WASTE WATER IN THE NETHERLANDS***

by

Dr. F.A.M. de Haan* and P. J. Zwerman**

INTRODUCTION

In this paper the results of a study about the possibilities for land disposal of starch processing water are discussed. Land disposal of process water, combined with agricultural use of the nutrient elements of this waste water, has to be subjected to a number of stipulations of which the most important one is: the amount of water that can be purified by the soil. Important is the utilization of the nutrient elements in the growing plant as is the effect of land disposal on farm economics. The technical elaboration of water distribution together with all the above aspects were studied by a special working group. The results of these studies have been described in a report (1). Here the presentation of data is confined to the first topic, viz. the purification by the soil. Results of related studies on other topics will be briefly described in the discussion.

The northeastern portion of The Netherlands is included in the so called Veen Colonies, with a total area of approximately 70,000 hectars. The soil is made up of sandy subsoil and of the previous organic soil, covered with low grade organic matter not suitable for the preparation of fuel (2). With the latest methods of land preparation being utilized approximately 35,000 hectars are annually utilized for the production of starch potatoes.

The starch from these potatoes is produced in some 13 factories, spread over the area. This results in a tremendous quantity of waste water that is released on open cannels and water ways, and in this manner is led off to the Eems Dollard estuary and Lake IJssel. This method of disposal of waste from the starch industry was utilized since the second half of the previous century. The pollution of surface waters and the excessive stink, as a consequence of the rotting of proteins in the waste water, will no longer be tolerated.

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***Agronomy Paper No. 1008.

The potato starch industry is a typical seasonal processing industry. All potatoes are processed during the period from the middle of August to the middle of December. After arrival at the factory the potatoes are washed and transported by means of water to the actual site of extraction of starch. This results in the first kind of waste water, viz. the wash and transport water. It contributes scarcely 5% to the total waste burden. Especially, at the refinery procedure of the starch, large quantities of water are used. The present average production of processing water amounts to approximately 8 m^3 per ton of potatoes. However, the tendency exists to arrive at a limitation of water utilization by application of washing against the stream.

The total capacity of the 13 factories is 1,160 tons of potatoes per hour and the average duration of working hours for a campaign is 2,200 hours; thus about 20 1/2 million cubic meters of process water is produced annually. This coincides on the base of biochemical oxygen demand with a waste burden of almost 21 million human equivalents.

REVIEW OF LITERATURE

Recently various studies have been performed to evaluate the best solution for this waste water problem. Thus a proposal was made to lead all the waste water to the Eems Dollard estuary by means of an underground pipeline (3). This has led to numerous discussions; biologists fear for an excess of the self purification capacity of the water in this estuary (4). A technological solution of the problem by making byproducts from the water in the form of proteins, although possible from a technical point of view (5), is excessively high in costs.

MATERIALS AND METHODS

The effect of land disposal on purification of the process water was studied by a comparison of the composition of the waste water and of the leachate from soils which had been flooded or sprinkler irrigated with a known amount of process water. To this purpose samples of the upper layer of the groundwater were collected by means of piezometers, with a filter at the bottom. In all samples chemical and biochemical oxygen demand was measured, as well as the concentration of a number of components, viz. N-total, NH_4 in inorganic form, NH_4 in organic form, NO_2, NO_3, total phosphate as PO_4, and K. Analyses have been performed according to the standard procedures applied for the examination of water and waste water (6, 7).

The soils used in the experiments were of average composition for that part of the country. A distinction was made between sandy soils, consisting of medium fine sand with a top layer of about 30 cm with an organic matter content of 5%, and soils with a relatively large amount of peat in the profile. All experiments were performed in the field, both on "new" soils as well as on flood fields which were used for about 40 years for land disposal of process water.

Since the limit of the purification capacity of the soil had to be determined in a short time period, this study should be looked upon more or less as a pilot study. The mechanism of purification as well as the water transport in the soil is now being investigated in the laboratory by means of column studies and analogous water transport models.

An indication of the influence of land disposal on the soil composition was obtained at a separate site, viz. a flood field of town sewage of which soil samples were collected during a time period of 10 years (8). Phosphate contents of these samples were measured according to the ammonium lactate extraction procedure, whereas potassium contents are expressed as mg K_2O per 100 gram of dry soil.

EXPERIMENTAL RESULTS AND DISCUSSION OF THESE RESULTS

The average composition of Dutch potato starch process water, at a waste water production rate of 8 m^3 per ton of potatoes, is presented in Table 1. These are the mean values of a large number of sampling dates. Process water production rates, and consequently the composition of the waste water, may slightly differ from one factory to another, depending on the refinery procedure applied.

Table 1. Average Composition of Potato Starch Process Water, in mg/l.

COD	BOD_5	N-tot.	NH_4 inorg.	NH_4 org.	NO_2	NO_3	PO_4	K
8,400	3,900	420	110	310	-	5	190	580

The very high oxygen demand values must be attributed to the presence of organic matter in the waste water. This organic material mainly consists of proteins. Nitrogen almost completely occurs as ammonium, with 3/4 in the organic form. In fresh process water nitrite was found not to be present at detectable concentration, whereas the nitrate content is very low. The phosphates consist for the major part of orthophosphates. Also small quantities of easily hydrolyzable polyphosphates were found. The high potassium content of the process water limits agricultural use. The water has to be disposed of in a potato growing area. High potassium availability in soil decreases starch content of potatoes.

Flooding of the land offers a means of disposal of large quantities of waste water. In the experiments amounts as high as 500 mm were added to both sandy and peaty soils. The effect on the composition of the upper groundwater layer is given in Table 2. For comparison data for untreated soil are also represented.

Table 2. Composition, in mg/l, of the Upper 50 cm Layer of Groundwater on Sandy and Peaty Soils After Addition of 500 mm Processing Water, in Comparison to Untreated Soil.

Soil	COD	BOD_5	N-tot.	NH_4 inorg.	NH_4 org.	NO_2	NO_3	PO_4	K
Sand	320	34	18	13	5	1.6	61	1.1	197
Peat	680	6	36	25	11	1.0	25	47	251
Untreated	56	2	2.3	1.0	1.3	0.2	17	0.3	15

It is shown that disposal of process water at this level results in an increase of all components in the groundwater as compared to the untreated soil. However, the degree of purification, expressed as a percentage removal from the waste water (cf. Table 1) is extremely high. Only potassium is removed to a minor degree which is in accordance with the limited adsorption capacity of the soils under consideration.

A remarkable difference exists between the sandy soil and the peaty soil. Due to precipitation as Fe- and Al-phosphates, phosphate removal is almost complete in sand, whereas on the peaty soil about 75% removal only is obtained. This percent may still be reasonably high in comparison to normal biological waste water treatment. The remaining phosphate concentration, however, is considered as much too high with respect to eutrophication (9). Whether or not eutrophication will be induced by these phosphates depends on the reactions which may occur before the groundwater reaches the open water. Also nitrate may contribute to eutrophication, especially on the sandy soil, whereas a consequence of better aeration conditions for biological decomposition of the organic matter, nitrate concentrations of the groundwater are high as compared to the peaty soil. These nitrates may easily be transported to the open water, unless denitrification takes place.

The influence on the composition of deep groundwater was also studied. For this purpose samples were taken at a depth of 60 meters under the flood fields which have been used for 40 years for land disposal of processing water. The results are presented in Table 3. The soil at these plots is sandy over the entire depth of 60 meters.

Table 3. Composition of Groundwater, in mg/l, at a Depth of 60 meters Beneath Flood Fields, Which Have Been Flooded During 40 Years With a Yearly Amount of 500 mm Potato Starch Waste Water.

COD	N-tot	NH_4 inorg.	NH_4 org.	PO_4
60	1.0	0.9	0.1	0.8

At this depth there seems to be no influence of land disposal on the ground water composition.

In the first days after addition of these large amounts a temporary increase of oxygen demand in the upper groundwater was found. Sometimes this was up to a BOD_5 of 1,000 mg/l. In a separate experiment the effect of partial additions was studied. For this purpose an amount of 420 mm was applied at once, and also in 3 portions of 140 mm with time intervals of 3 weeks. Only part of the 140 mm could be stored in the profile. It was found here that 140 mm were completely purified; between the second and third applications a sharp increase of oxygen demand was measured.

Application by means of sprinkling irrigation is advantageous in that the addition can be controlled much more accurately than with flooding. This is of special importance as the process water production will decrease in the future. A proportional increase of the waste water concentration will then result, which requires an accurate distribution system with respect to plant nutrition.

An amount of 40 mm was applied by sprinkling on a sandy soil (10). This quantity was sufficiently small not to exceed the unsaturated soil water storage capacity. The course of COD, BOD_5 and N-total as a function of time is presented in Figure 1. Application was performed at the end of September. At the end of December and in March heavy rainfall occurred, which at that time still caused a small leaching of organic matter. After leaching the composition of the groundwater gradually improves again.

Unfortunately data of soil analyses from plots of soils flooded for many years with processing water are not available.

Provided that adequate applications are choosen, land disposal of processing water will meet purification requirements for such a time period. Yearly additions of 400-500 mm result in a temporary high oxygen demand of groundwater. It is suggested that application must not exceed 100-500 mm per year. This amount must preferably be disposed of in portions of 40-50 mm. So one maintains optimal aeration conditions for biological decomposition of the organic material.

GENERAL DISCUSSION

As a consequence of the tremendous amount of process water land disposal must, from an economic point of view, be combined with agricultural use of the nutrient elements in crop growing. In addition to the resulting economic advantage, this induces a recycling which should be preferred from an environmental point of view. Moreover this recycling enlarges the purification capacity of the soil. To suit the application to the plant nutrient requirements, the working coefficient of the different nutrient elements of process water for different crops was determined in separate experiments (11). With the use of these values, and the relation between fertilization and crop yields the savings of expenses for fertilizers were calculated for all rates of application. On the other hand, yield depressions as a consequence of non-optimal meeting of nutrient requirements and application rates must also be taken into account. Moreover the farmers experience disadvantages as the water is disposed of in fall when there is no need for extra water and the disposal may force delay of farm operations. All these and related factors were taken into account in a computerized model study (12). This study showed results in a farm economic advantage of about 100 Dutch guilders per hectar per year at an application rate of 100 mm. This application is the average value for the entire farm. An optimalization was performed with respect to different crops of the most common crop rotation schedules for this area. So if the crop growing area is covered for 50% by potatoes, as actually is the case in this area, the other crops as grains and sugarbeets will receive 150 mm, since potatoes allow an application of 50 mm only.

In a case study for one of the factories a plan for disposal of all the process water of this factory in a continuous program during the campaign was worked out for flooding as well as for sprinkling irrigation. Flooding turned out to be almost twice as expensive as sprinkling irrigation. High costs for flooding are mainly due to the required land levelling and drainage systems. As was pointed out before purification of the water is also best served by sprinkling irrigation. Yearly costs for application by sprinkling at a rate of 100 mm were found to be 380 guilders per hectar. Thus leaving net expenses for land disposal of about 280 guilders per hectar. It may be reasoned that the farmers pay their economic advantage back to the land disposal system. This is true because they contribute to the pollution by growing these starch potatoes, whereas at the same time the farmers are in general the cooperative owners of the factories.

For a "standard" factory with a capacity of 100 tons of potatoes per hour, a yearly working period of 2,200 hours and a waste water production of 8 m^3 per ton, land disposal will lead to yearly expenses of about half a million guilders. Such a factory produces a waste burden comparable to 1.8 million human equivalents. Costs for land disposal are thus about 0.3 guilders per human equivalence, as compared to about 10 guilders for biological treatment of the waste water. This number has a limited value only since data were derived for one specific factory only. However, even if the extrapolation to other situations would increase the costs by a factor of two, land disposal still remains a relatively inexpensive and good solution of this specific industrial waste water problem.

SUMMARY

Possibilities for and implications of land disposal of potato starch processing water are discussed. In a series of experiments the purification by soil was studied from the composition of the upper groundwater after different additions of process water. Removal of oxygen demand from the waste water as well as of different components was found to be complete on sandy soils, except for potassium, if application does not exceed 100-500 mm. At higher doses a temporary high increase of oxygen demand of groundwater was measured. Peaty soils turned out to be less effective in purification, especially with respect to oxygen demand and phosphate removal. Aeration conditions in the soil should be maintained at optimum for biological decomposition of the organic matter. In this respect the waste water must preferably be applied by means of sprinkling irrigation, at doses not exceeding 40-50 mm. In this way land disposal may be an effective method for process water treatment during a time period of at least 30-40 years. Due to the small adsorption capacity of the soils studied and the high potassium content of the waste water, a considerable part of the potassium applied will be leached. Land disposal in combination with agricultural use of the plant nutrients leads to a relatively inexpensive way of potato starch waste water treatment.

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PRETREATMENT OF COMBINED MUNICIPAL AND POTATO PROCESSING WASTES

by

Guilford O. Fossum*

This paper presents a progress report on research being conducted on the aerated and anaerobic pretreatment of combined municipal and potato processing wastes at Grand Forks, North Dakota. Data is presented for only the first year of operation dating from 1 January to 31 December, 1972. It discusses some of the physical and chemical parameters, but excludes the data gathered on bacteria, algae and other organisms which will be available from others at a later time.

ACKNOWLEDGMENT

This study was supported in part by funds received under Grant No. 11060-DJB from the Federal Water Pollution Control Administration of the U.S. Department of the Interior to the City of Grand Forks, and in part from funds supplied by the City of Grand Forks, North Dakota.

INTRODUCTION

The City of Grand Forks, North Dakota, is located in the Red River Valley at the junction of the Red River of the North and the Red Lake River. It is situated in the heart of a rich agricultural area whose principal products are small grains, potatoes and sugar beets. The city has a population of approximately 40,000 and the principal industries are the potato or grain processing types. All sewage, domestic and industrial, is sent through the city system for final treatment and disposal, some on-site pretreatment being done by the potato processors.

The use of conventional lagoons or stabilization ponds for sewage treatment has become very common in North Dakota because large areas of relatively inexpensive land are usually available. These "conventional" ponds are normally operated in a depth range of from 3 to 5 feet and the raw sewage enters these ponds without pretreatment. Stabilization occurs from the natural action of aerobic organisms receiving oxygen from wave action or from photosynthesis from algae present. In most cases the effluent is discharged to surface streams when the necessary degree of treatment has been obtained to meet the water quality standards for the receiving stream. Design criteria for these ponds has normally been an organic loading of 20 pounds of BOD per acre per day (all useage of BOD in this paper refers to the standard 5-day 20° Centigrade value). Ice cover and cold temperatures slow down the biological action during the winter months so that hydraulic considerations become important in that a storage period of 6 months or more may be necessary before the effluent reaches satisfactory quality for discharge.

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In 1962 such a stabilization pond system was put into operation at Grand Forks. The system consisted of two primary and two secondary cells with a combined water surface of approximately 585 acres. At that time, it appeared that this system would meet the needs of Grand Forks for quite some time as no serious problems were anticipated for a population equivalent approaching 100,000. During the 1960's, however, there was a dramatic increase in the use of processed potatoes(1), and by 1967 expansion of the potato processing industry at Grand Forks had occurred to the point where it was apparent that it was going to be necessary to make modifications in the waste disposal system. The BOD loading on the ponds had reached about 12,000 pounds per day and this was expected to increase to about 25,000 pounds per day with the annexation of a large industrial area.

To meet the situation, the City of Grand Forks in 1968 applied for and received a Research and Development Grant from the Federal Water Pollution Control Administration (FWPCA), Department of the Interior. The project was entitled "Controlled Treatment of Combined Potato Processing-Municipal Wastes by Anaerobic Fermentation, Aerobic Stabilization Process". The stated objectives were, in part, to demonstrate, develop, and evaluate joint treatment of potato processing - municipal wastes by use of stabilization pond pretreatment methods consisting of anaerobic treatment, aeration treatment, and anaerobic-aerated combination treatment. A research period of 18 months was involved but contractual and construction obstacles delayed the project until 1 January 1972, for beginning collection of operating data.

PRETREATMENT FACILITIES

Surveys of the waste being produced by the potato industries indicated that a daily loading of about 33,000 pounds of BOD could be expected from this source. At the same time the other municipal sewage was expected to give a loading of about 11,000 pounds per day for a total of 44,000 pounds of BOD per day. A recently passed industrial waste ordinance, however, was expected to reduce the industrial waste load to about one-half of the organic loading with no appreciable change in the expected hydraulic loading of between 4 and 4.5 million gallons per day. Considering all these factors, it was decided to design the pretreatment facilities on the basis of 25,000 pounds of BOD being applied per day with a flow rate of 4.2 mgd.

Experience with the existing stabilization ponds indicated that no serious problems were to be expected if the loading were kept to a maximum of 12,500 pounds per day during the cold weather season. This amounts to a gross loading of about 21.4 pounds per acre per day, or about 40.4 pounds per acre per day on the primary cells alone. To reduce the incoming load to a value of 12,500 pounds per day the pretreatment cells would have to reduce the BOD by at least 50%.

Available data on the raw sewage indicated that it should arrive at the treatment site with a temperature between 10 and 15 degrees Centigrade during the coldest weather. Since it was not planned to cover the cells, the operating temperature was estimated to be between 5 and 10°C in midwinter in the aerated cells. Calculations indicated that at this temperature a detention time of 4 days would probably give a BOD reduction very near the required 50%. On the basis of these projections the pretreatment cells were designed as shown in Figure 1, each cell being about 320 feet square at the water line, 15 feet maximum depth, with a volume of 8.6 million gallons. Two of them were designed to be unmixed anaerobic cells, and the other two were each equipped with 4 aerating and mixing units. Thus, if all the sewage is to pass through aerated cells, the detention time in the aeration units is about 4 days. As an additional factor of safety against greater loadings than anticipated, or other unforeseen conditions, no BOD reduction was assigned to the anaerobic units. The cells are so arranged that portions may be operated anaerobically, aerated, or in series.

Each of the 8 aeration-mixing units is platform-mounted and the impeller is driven by a 60 hp electric motor. Compressed air from the compressor building is piped in and released below the impeller which is submerged within a couple of feet of the bottom of the cell. The air is supplied by 5 rotary air compressors, each driven by a 75 hp electric motor. The air is piped separately to each of the two aerated cells and at each mixer a valve is used to further regulate air flow. The original specifications required that the aeration equipment for each cell be capable of transferring 440 pounds of oxygen per hour to pure water at 20°C, 760 mm Hg pressure, and zero dissolved oxygen. A central meter house and distribution box allows control of the flow to each of the four cells.

The raw sewage flow is metered by one totalizing and recording magnetic meter at the central meter house. The effluent from the cells is metered by either one or two meters depending on the flow pattern being used.

PROCEDURE

During the first 12 months of operation, three different flow patterns were used concurrently. These patterns were begun about 1 January, 1972, and were operated without change until 31 December, 1972. Part of the data collected from these three patterns is the basis of this report. The patterns were as follows: (a).One-fourth of the raw sewage was sent to the north anaerobic cell (NAN) from where it was metered out through the north effluent meter directly to the east primary cell of the large ponds. (b). One-fourth of the raw sewage was sent directly to the north aerated cell (NA). It then went through the south effluent meter and on to the west primary cell of the large lagoons. (c). One-half of the raw sewage went to the south anaerobic cell (SAN) and then to the south aerated cell (SA). It then joined the effluent from NA and proceeded through the south effluent meter to the west primary. Thus, one-fourth of the flow received anaerobic treatment only before going to one of the primary ponds of the system. The rest of the flow went through the aeration process and then was sent to the other primary pond. The two aerated cells were kept fully mixed at all times by operating all 8 mixers continuously. The number of air compressors on line was anywhere from one to five depending on the demand for oxygen. It was attempted to maintain not less than one mg/l of dissolved oxygen in the effluent from the aerated cells.

Sampling was conducted on a weekly basis with composites being collected for approximately a 24-hour period on the raw sewage and the effluents

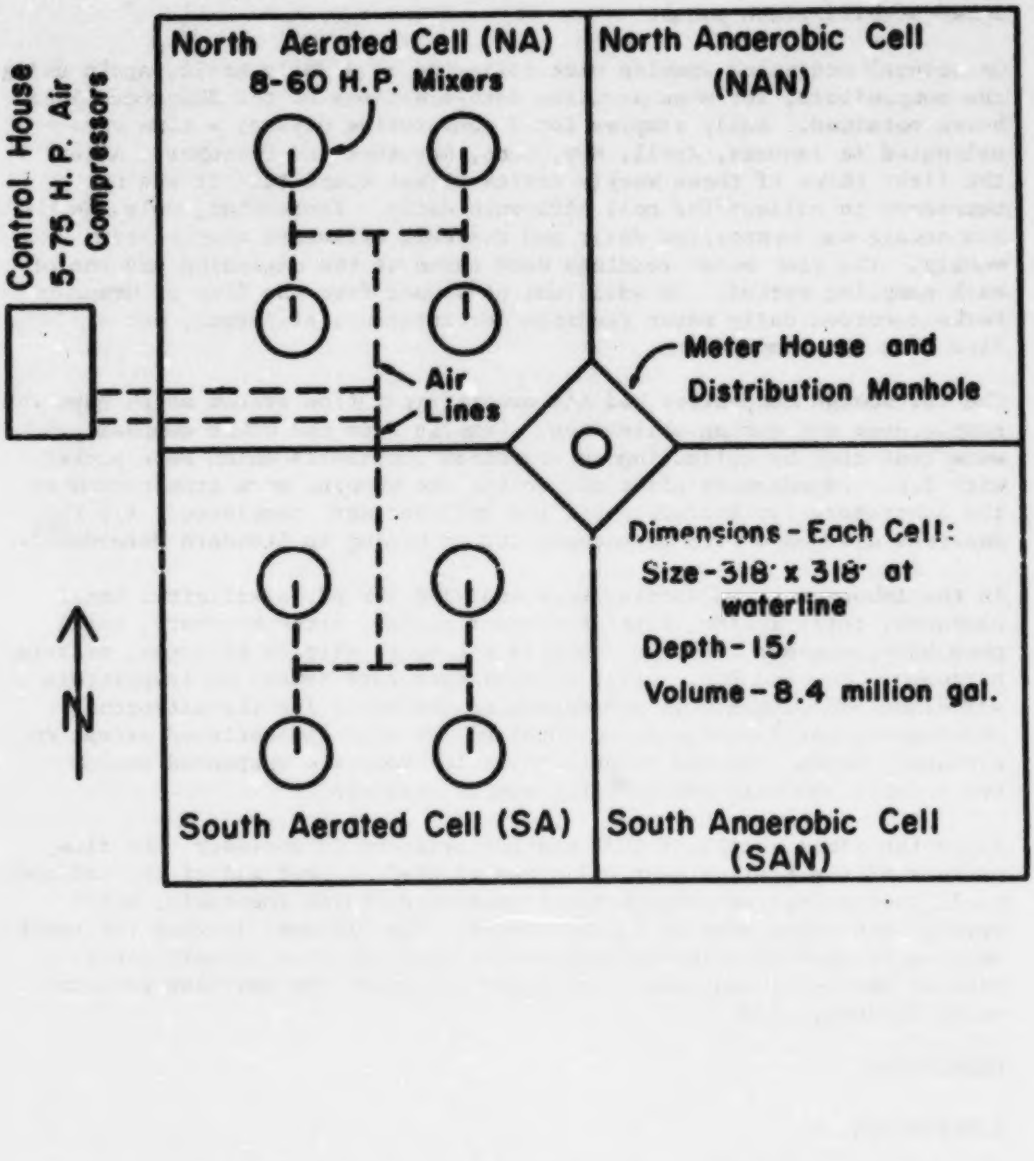

North Aerated Cell (NA)
8-60 H.P. Mixers
North Anaerobic Cell (NAN)
Control House
5-75 H.P. Air Compressors
Air Lines
Meter House and Distribution Manhole
Dimensions - Each Cell:
Size - 318' x 318' at waterline
Depth - 15'
Volume - 8.4 million gal.
N
South Aerated Cell (SA)
South Anaerobic Cell (SAN)

Figure 1. PLAN OF PRETREATMENT CELLS

from each of the four cells. From January through June the composites were generally collected between Wednesday morning and Thursday morning. From July through December the pattern was changed to collect composites from Tuesday morning until Wednesday morning. Grab samples were also taken for analysis of bacteria, algae, and other plankton and microorganisms. Also, occasional grab samples were collected from the four large stabilization ponds.

On several occasions samples were collected on a daily basis, again using the compositers, for more accurate determinations of the BOD reductions being obtained. Daily samples for 7 consecutive days at a time were collected in January, April, May, June, November and December. After the first three of these weekly series it was found that it was not necessary to collect the cell effluents daily. Thereafter, only the raw sewage was composited daily and the cell effluents composited weekly. The flow meter readings were taken at the beginning and end of each sampling period. In addition, personnel from the City of Grand Forks recorded daily meter readings for influent, effluents, and air flow from the compressors.

The raw sewage compositer had its own refrigeration system which kept the sample near 5°C during collection. Samples from the other compositers were kept cool by collecting in styrofoam containers which were packed with ice. Immediately after collection the samples were transported to the laboratory for storage until the analyses were completed. All the analyses discussed here were conducted according to Standard Methods(2).

In the laboratory the samples were analyzed for pH, alkalinity. total hardness, total solids, total suspended solids, orthophosphate, total phosphate, organic nitrogen, ammonia nitrogen, nitrite nitrogen, nitrate nitrogen, COD, and BOD. Field measurements were taken for temperature and dissolved oxygen. In mid-September the tests for the nitrogens, phosphates, total hardness and total solids were discontinued except on a monthly basis. In mid-October tests for volatile suspended solids and soluble BOD were added to the weekly analyses.

After the final sample of 1972 was collected on 27 December, the flow pattern of the pretreatment cells was altered so that all of the influent would flow in series through south anaerobic, north anaerobic, north aerated and south aerated in that order. The effluent leaving the south aerated is then distributed between the east and west primary ponds. Similar data will continue to be collected under the new flow pattern until 30 June, 1973.

DISCUSSION

Temperature

Temperature variations of the raw sewage, the south anaerobic and the south aerated cell are shown in Figure 2. The aerated cell had temperatures somewhat lower than the 5 to 10°C that had been predicted for about 3 months out of the year during which time it averaged about 1.5°C. From mid-April until mid-November the aerated cell had higher temperature than the anaerobic cell; the anaerobic cell was warmer than

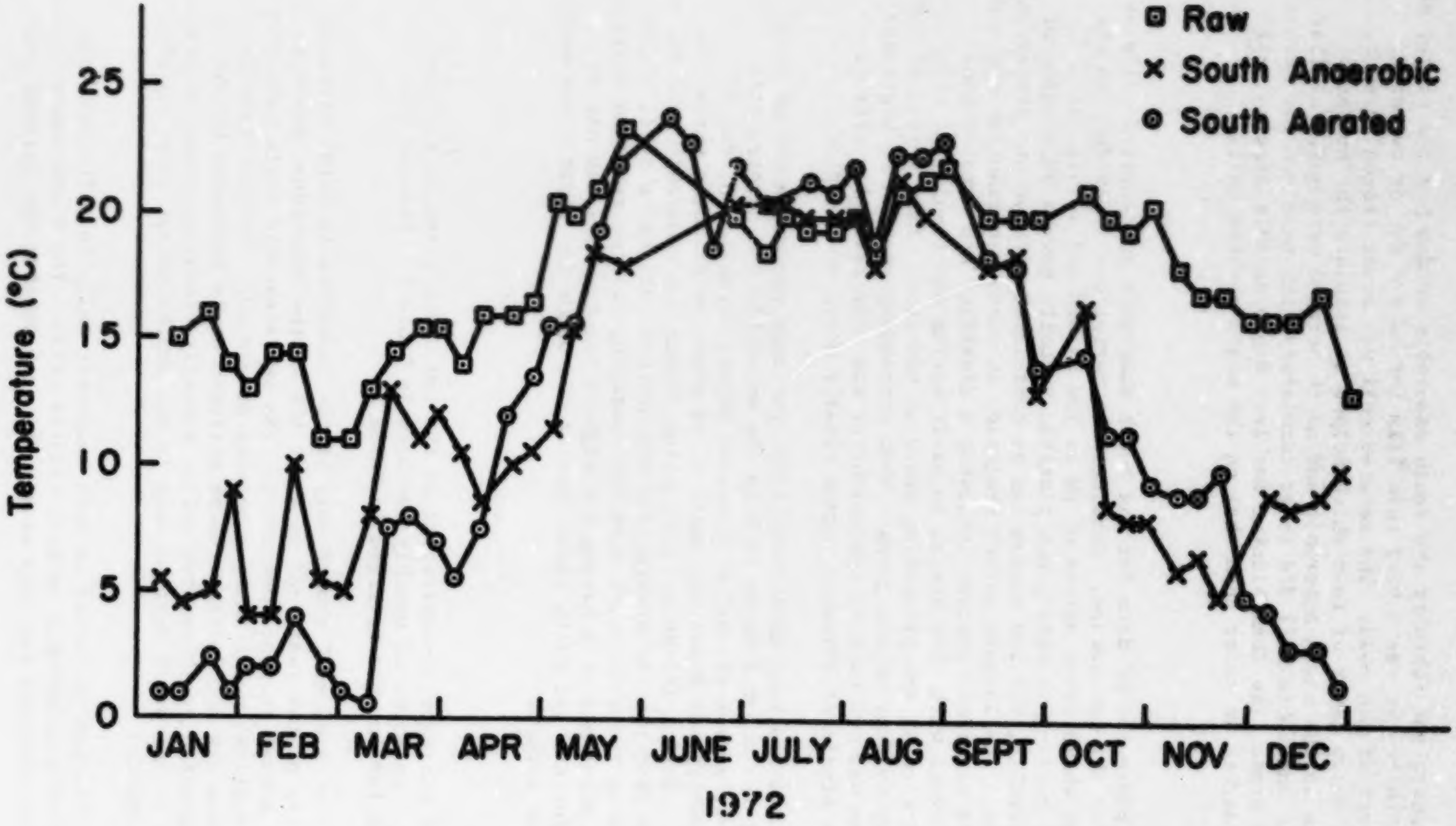


Figure 2. TEMPERATURE

the raw sewage only between mid-June and the first of September.

During January and February the south anaerobic seldom had ice cover, and when it occurred it was a very thin film for only a day or two at a time on part of the pond. The aerated cell was never frozen as such, but had a heavy layer of foam which helped to insulate the surface. Conditions in the north anaerobic and north aerated were quite similar except the anaerobic cell did cover completely with thin ice for several days at a time. The foam blanket was less dense on this aerated cell and also darker in color than that on the south aerated cell.

pH

Figure 3 plots the pH data for the south anaerobic and aerated cells as well as for the raw sewage. Considerable variations is evident in the raw sewage which shows values of pH as low as 6.0 and as high as 7.7. One daily reading in April, not plotted, actually gave a pH reading of 5.7. Generally, the low values can be correlated with potato processing operations. The largest potato processor in waste contribution operated an on-site treatment process involving a clarifier and aerated ponds. Problems arose with this system in early spring and finally it became inoperative until the processing ended in mid-June. This period of low pH is very evident on the graph. When processing resumed in September the system was put back in operation but was only partially effective until the middle of November, again clearly shown on the plot.

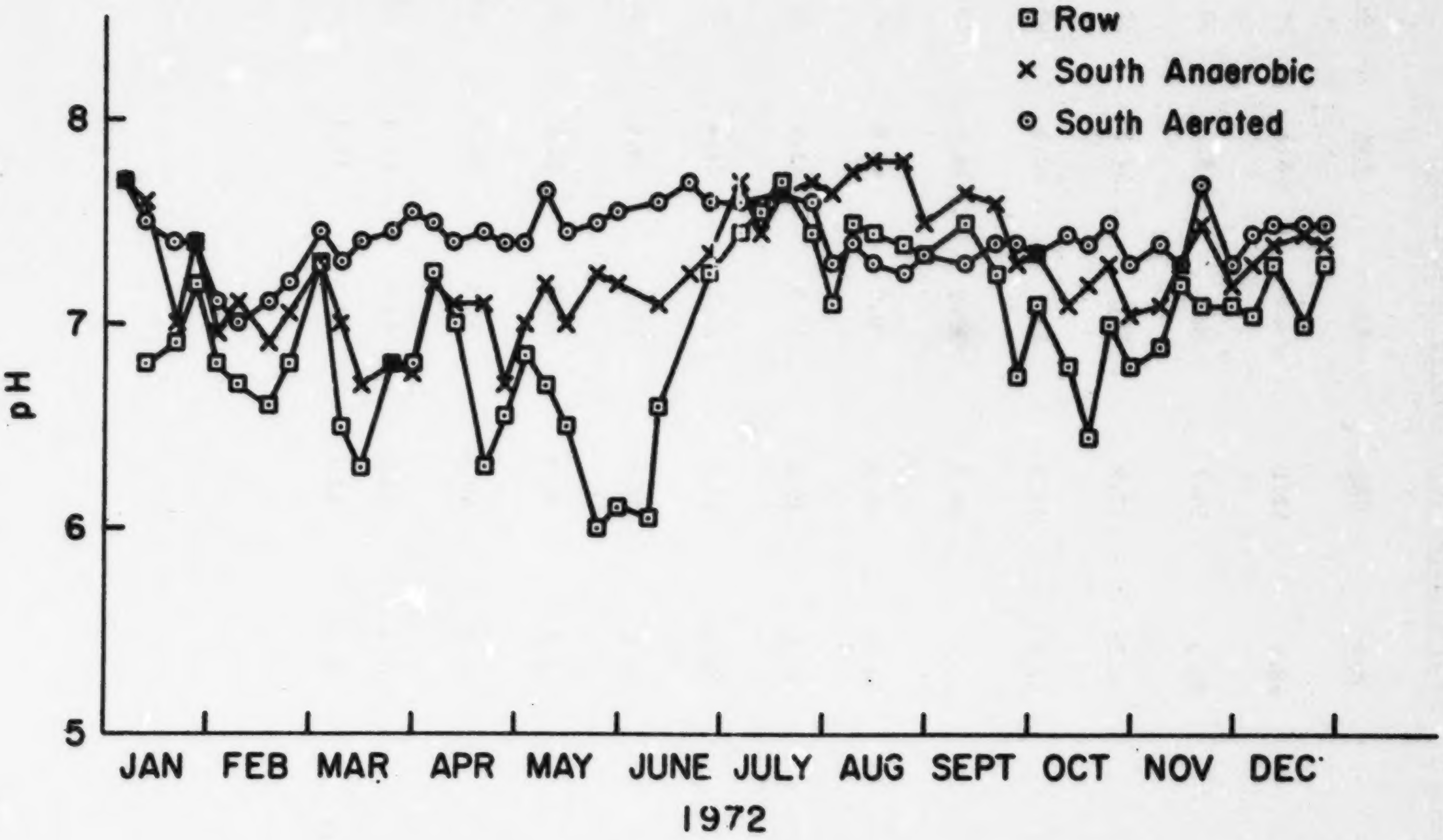
When the pretreatment cells were first put into operation the pH fell gradually for about 6 weeks in both the anaerobic and aerated cell. Thereafter, as the effective organisms became established, the pH rose gradually for about one month after which no dramatic variations occurred. During the potato processing season the anaerobic cell had a higher pH than the raw sewage, and the aerobic cell had a still higher value. When the processors were not operating the two reversed positions with the anaerobic cell having the highest value. This was not as evident for the two north cells, but it did occur for about a one-month stretch in August.

Nitrogen

The total nitrogen concentration in the raw sewage, and in each cell effluent, is shown as monthly averages in Table 1. Similar data is presented for ammonia nitrogen in Table 2.

The north aerated cell showed very little reduction in total nitrogen at any time of the year, and in about 40% of the individual readings taken an actual increase was noted. The two anaerobic cells gave very nearly identical reductions, generally around 20%. Further treatment by aeration did not further remove nitrogen as is indicated by the series-operated south aerated cell. Actually, total nitrogen increased slightly in the south aerated cell in all months except July, August, and September.

Ammonia nitrogen increased in both anaerobic cells in all cases, but was reduced considerably in both aerated cells. The final concentration of ammonia nitrogen was very nearly the same whether the aerated cell


Raw
× South Anaerobic
South Aerated
pH
8
7
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JAN
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OCT
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DEC
1972

Figure 3. pH

Table 1. Total Nitrogen (mg/l as N) By Monthly Average

Month	Raw	NAN	NA	SAN	SA
Jan.	68.4	52.1	64.0	48.5	54.8
Feb.	89.3	50.7	76.0	48.7	50.6
Mar.	80.3	52.9	78.9	52.3	52.3
Apr.	52.8	43.3	63.3	42.3	45.0
May	57.4	50.6	57.0	49.4	49.8
June	49.4	45.4	50.0	43.8	45.4
July	34.2	35.2	24.5	33.9	31.9
Aug.	33.1	32.9	24.1	31.8	22.9
Sept.	35.6	36.2	27.4	35.6	30.8
Oct.	46.0	39.0	49.2	39.0	39.6
Nov.	47.2	40.8	52.4	39.2	40.8
Dec.	56.4	42.0	62.6	40.4	42.8
Average	54.2	43.4	52.5	42.1	42.2

Table 2. Ammonia Nitrogen (mg/l as N) By Monthly Average

Month	Raw	NAN	NA	SAN	SA
Jan.	25.5	29.8	16.1	29.5	17.9
Feb.	25.5	29.6	16.3	27.4	15.7
Mar.	20.6	25.8	10.8	25.5	10.1
Apr.	22.9	27.2	7.8	27.1	9.3
May	27.9	37.9	7.4	37.1	10.6
June	23.1	34.4	11.4	33.1	11.6
July	23.6	28.7	13.1	28.0	19.5
Aug.	22.9	27.1	11.1	26.2	13.3
Sept.	23.1	29.9	20.4	27.6	13.1
Oct.	23.0	27.4	7.1	29.2	9.3
Nov.	25.6	31.2	12.0	31.6	18.0
Dec.	23.2	30.5	19.1	29.5	18.3
Average	23.9	30.0	12.7	29.3	13.9

was preceded by an anaerobic cell or not. Based on the raw sewage, the aerated cells decreased ammonia content by about 50%. The relative concentration of ammonia nitrogen in the south anaerobic and south aerated cells is shown in Figure 4. The relative differences are quite consistent except during the period when the on-site treatment facilities were not operating properly for the large potato processor.

Phosphate

Tables 3 and 4 show the monthly averages of the phosphate (PO_4) concentration as total phosphate and orthophosphate, respectively. Both tables indicate that the pretreatment system was ineffective in the removal of phosphates. At times the anaerobic cells showed some decrease in total phosphate because of sedimentation of solids, but at times when influent phosphate was low there was an increase in these cells. The orthophosphates increased in the anaerobic cells and then decreased again in the aerated cell for series operation. Overall reduction was negligible, however. A recent study of aerated lagoons at Winnipeg, Manitoba, indicated total nitrogen reductions of about 12%, and about 20% reduction of total phosphate(3). However, detention times in these cases were 20 to 30 days. A study by others of treatment of pea processing wastes indicated no significant reduction of nutrients by an aerated lagoon(4).

Suspended Solids

Figure 5 compares the total suspended solids in the north anaerobic and north aerated cells with the raw sewage. The two south cells are shown in a similar manner on Figure 6. During the first four months of the year the suspended solids in the incoming sewage were very erratic from week to week. The lowest value during this period occurred on 2 March when a reading of 185 mg/l was obtained. One week later, on 9 March, the highest reading of 1175 mg/l was recorded. Both anaerobic cells were effective as settling basins in that the effluent suspended solids were seldom greater than 125 mg/l and for 70% of the time in the south anaerobic the readings were below 100 mg/l. There was also very little variation from week to week. Generally, the anaerobic cells reduced the suspended solids by about 85%.

The north aerated cell receiving raw sewage directly was also quite erratic in concentration of total suspended solids. As would be expected, the formation of biological floc caused an increase to occur. Because of the detention time and mixing in the aerated cell, relative values of raw sewage and effluent for a particular day vary greatly; however, when all readings are averaged, the north aerated shows an increase of about 15% in suspended solids over the raw sewage.

The south aerated cell had the benefit of the sedimentation in the south anaerobic and consequently the variations in suspended solids were less extreme. The bio-mass produced in the south aerated, however, caused an increase of approximately 3½ times of the suspended solids entering the cell. In absolute values the south aerated had only about 40% as much suspended solids as the north aerated cell and 50% as much as the raw sewage.

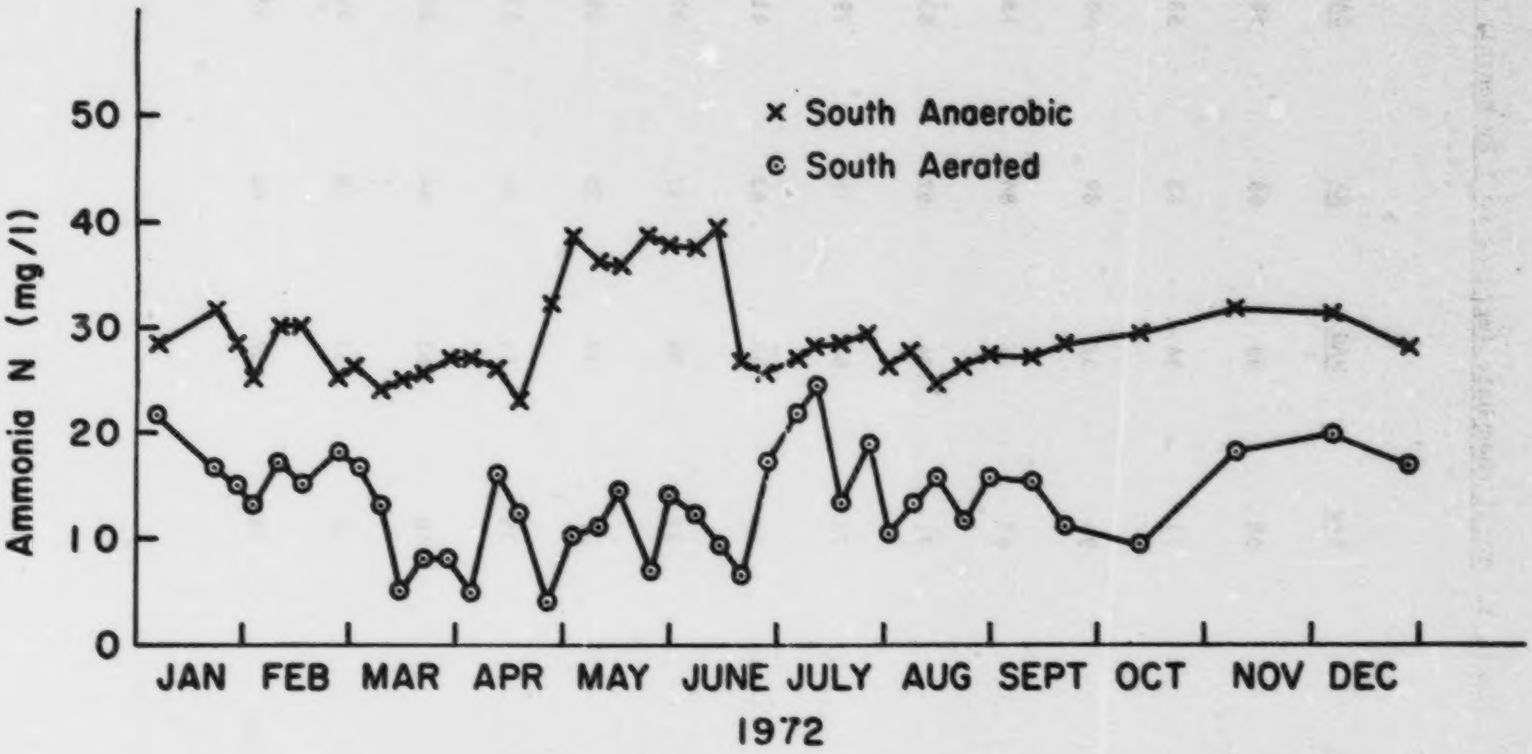

Figure 4. AMMONIA NITROGEN

Table 3. Total Phosphate (mg/l as PO_4) By Monthly Average

Month	Raw	NAN	NA	SAN	SA
Jan	68	59	64	58	60
Feb.	77	54	63	53	53
Mar.	90	58	89	60	58
Apr.	67	77	84	78	78
May	71	84	82	83	83
June	78	80	78	79	82
July	32	48	43	41	45
Aug.	33	39	37	37	38
Sept.	37	39	35	39	39
Oct.	35	54	34	53	54
Nov.	48	63	64	58	63
Dec.	58	57	68	56	59
Average	58	59	62	58	59

Table 4. Orthophosphate (mg/l as PO_4) By Monthly Average

Month	Raw	MAN	MA	SAN	SA
Jan.	46	48	37	47	41
Feb.	46	48	33	46	37
Mar.	46	50	36	52	40
Apr.	54	68	54	69	58
May	61	77	57	74	63
June	62	65	45	60	53
July	28	43	37	39	41
Aug.	30	37	31	36	34
Sept.	31	38	31	38	35
Oct.	34	46	30	48	39
Nov.	37	49	32	50	42
Dec.	32	47	35	46	40
Average	42	51	38	50	44

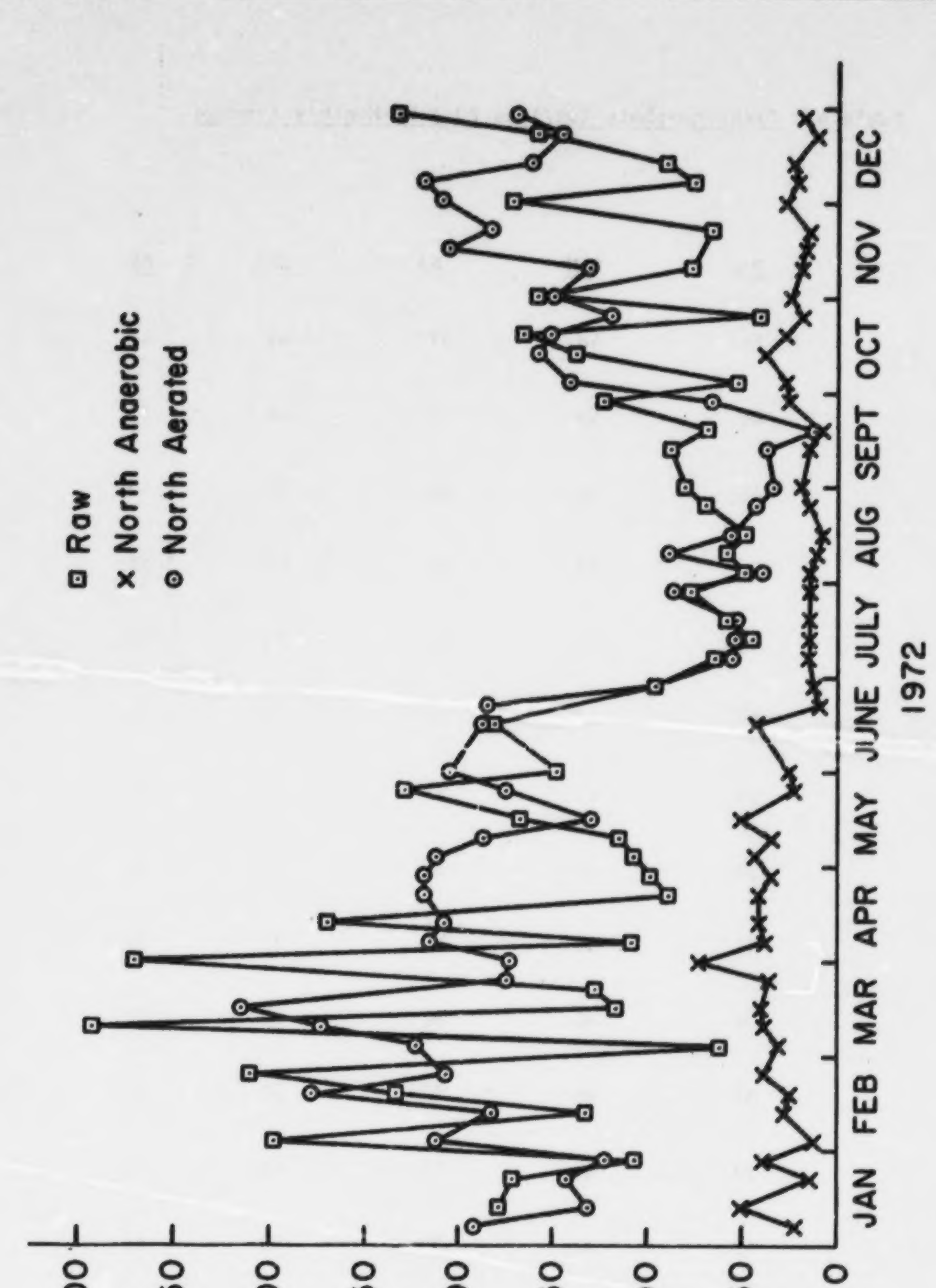

Figure 5. TOTAL SUSPENDED SOLIDS - NORTH

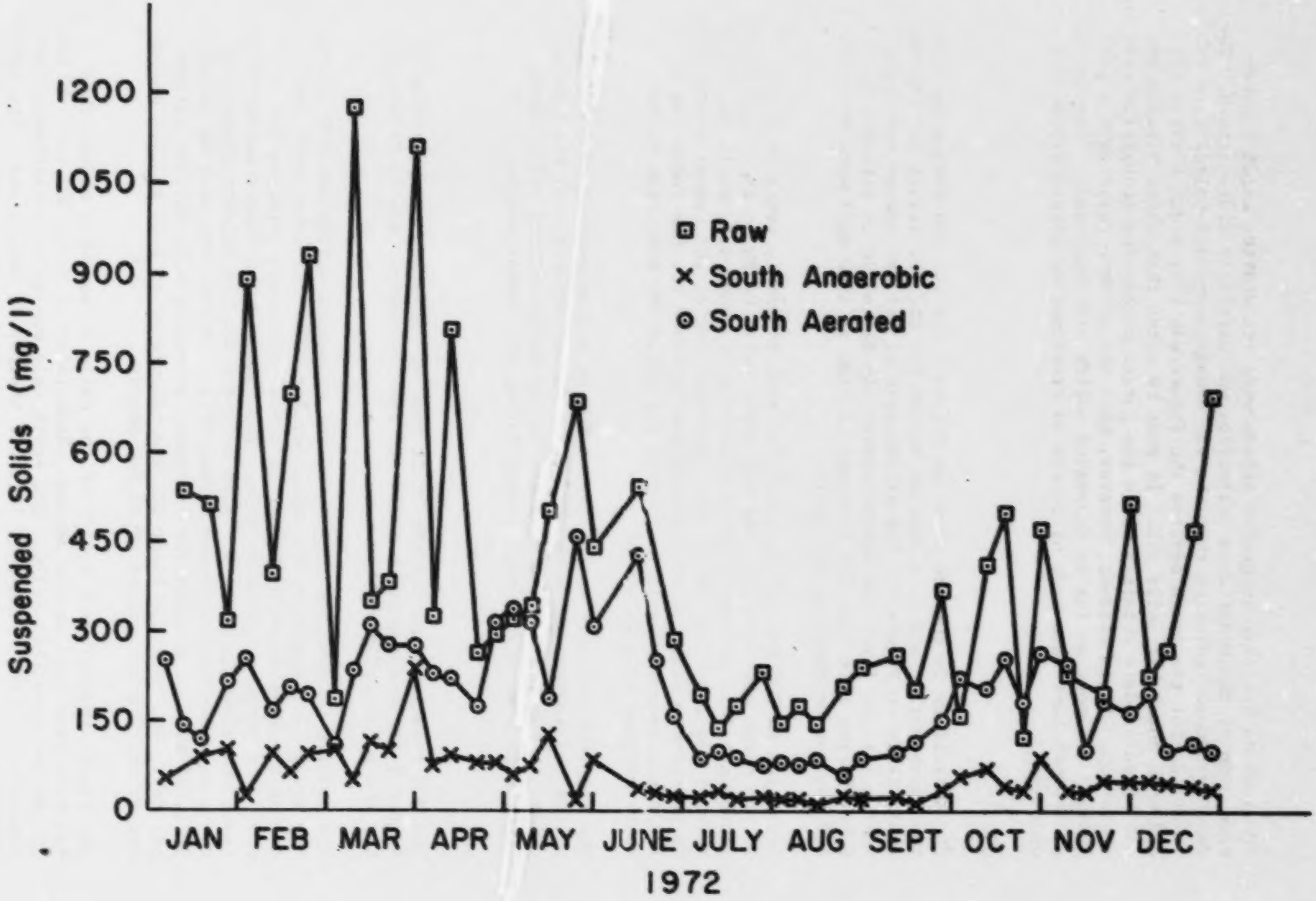

Figure 6. TOTAL SUSFENDED SOLIDS - SOUTH

Readings on volatile suspended solids were not started until October when some of the other data collection was partially discontinued. The data available indicates that the raw sewage suspended solids were 74% volatile; for the north aerated the figure was 78%, south aerated 89% and both anaerobic cells 91%. It must be noted that these figures are all based on data obtained while the potato processing industries were in operation. It is evident, however, that the aerobic cells gave a poor quality effluent as far as suspended solids are concerned. Similar statements have been made by others on treatment of potato processing wastes(5).

COD

The variations in COD are shown on Figure 7 for the raw sewage and the two north cells, and in a similar manner for the raw sewage and the two south cells on Figure 8. The erraticness of the raw sewage suspended solids for the first few months previously discussed is repeated for COD. During this time COD readings as high as 2700 mg/l were obtained and the low reading was 690 mg/l.

Reduction of COD was nearly equal for both anaerobic ponds as well as the north aerated pond, and was about 40%. Of these three cells, the south anaerobic had the highest reduction of about 42%, while the north aerated was lowest at about 36%. However, during the summer months when no potato processing wastes were being received the COD reduction in the north anaerobic cell fell below 25% while the reduction in the north aerated rose above 50%.

The anaerobic-aerobic series gave a COD reduction overall of 63% based on the raw sewage, while the reduction in the areated cell was practically the same as the 36% obtained in the north aerated cell. These figures show no significant change during the summer months.

BOD

The BOD relationships for the first year of operation are presented in Figure 9 for the two north cells and the raw sewage, and in Figure 10 for the south cells and raw sewage.

The erratic values that were noted for suspended solids and COD of the raw sewage are repeated, as expected, for BOD. Six tests were run during the year where each test involved continuous sampling for a period of seven consecutive days. The reductions obtained during these tests are given in Table 5. Also included are preliminary figures on the total reduction obtained during 1972. During the year an inflow of 1,666 million gallons was recorded, averaging 4.55 million gallons per day. The total influent BOD was calculated at 8.36 million pounds for an average daily load of 22,840 pounds.

The yearly reductions for each of the cells is somewhat higher than had been predicted in the design. Reductions of about 30% were obtained in the two anaerobic cells. The south cell was quite consistent, but reductions in the north cell fell off sharply at year's end. The reason for this is unknown at the present time. The south anaerobic gave 4.5%

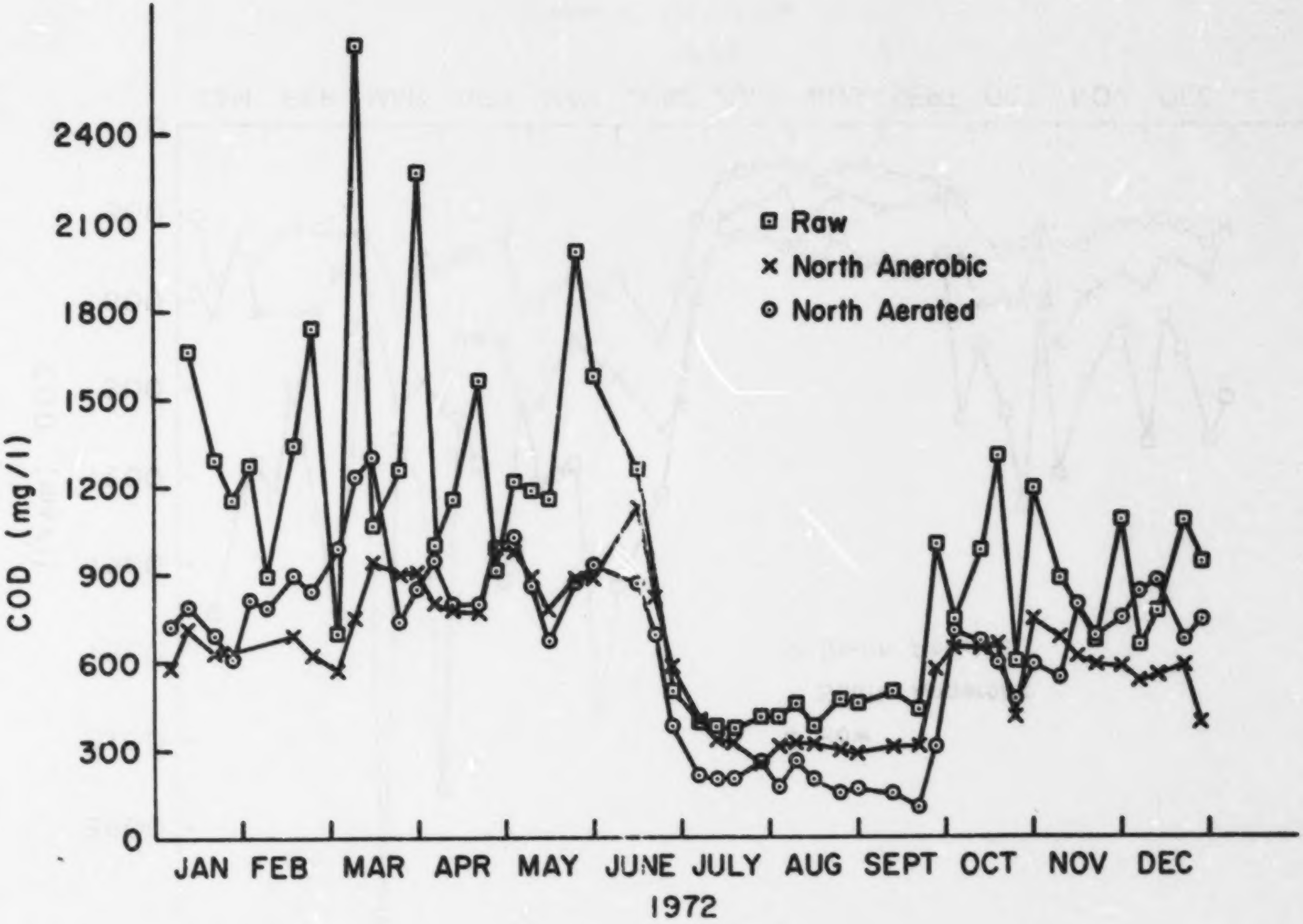

Figure 7. COD - NORTH

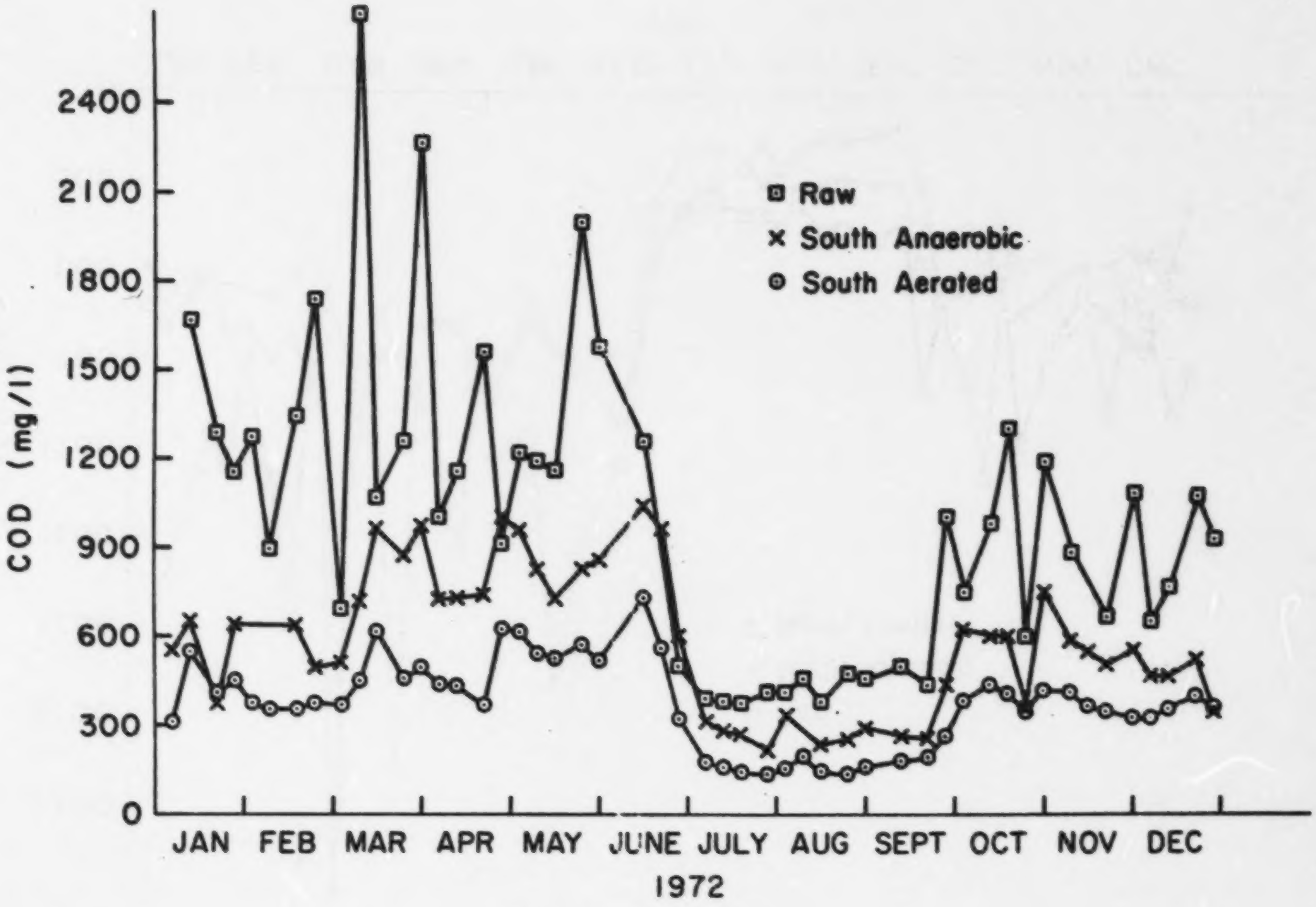

Figure 8. COD - SOUTH

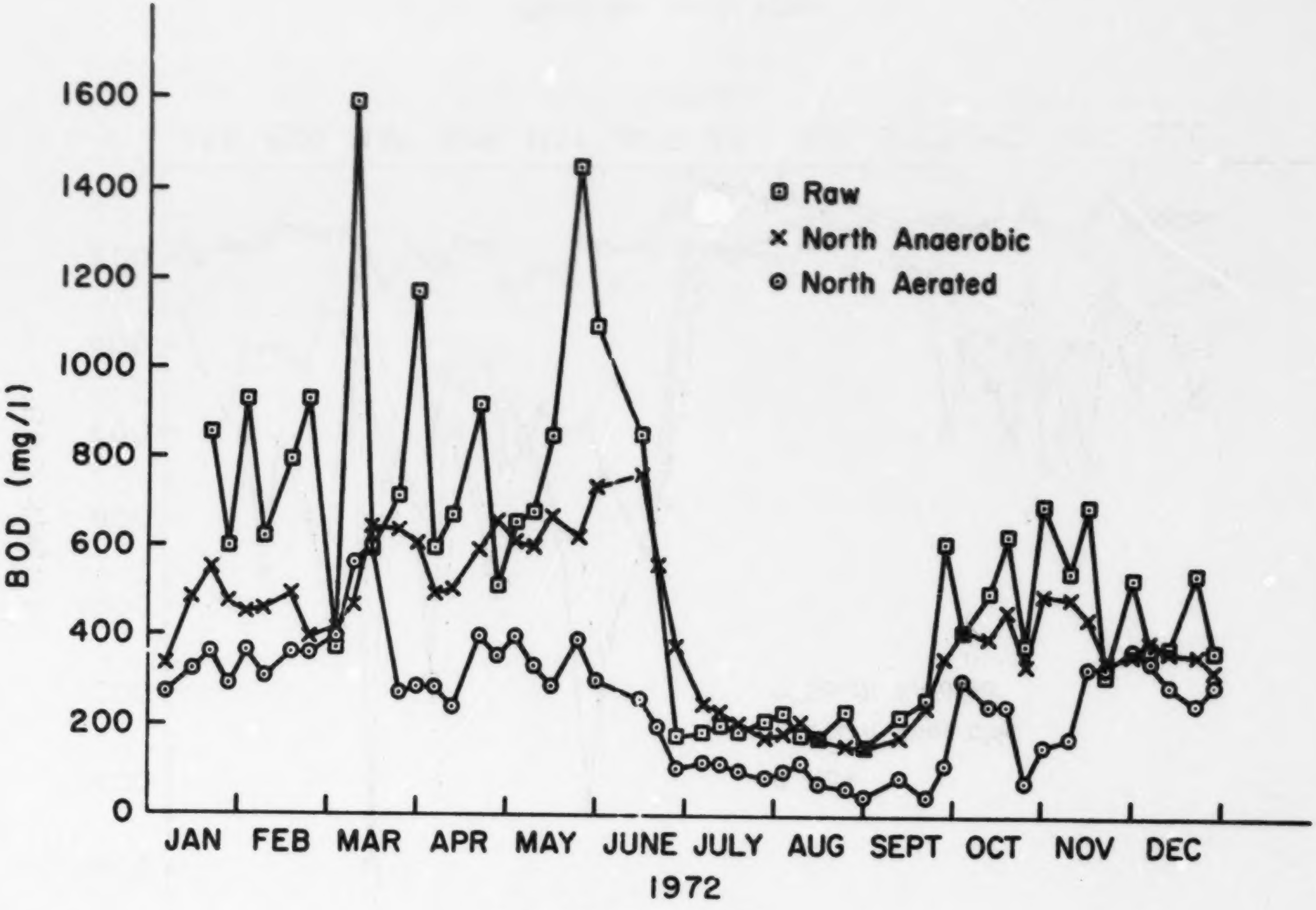

Figure 9. BOD - NORTH

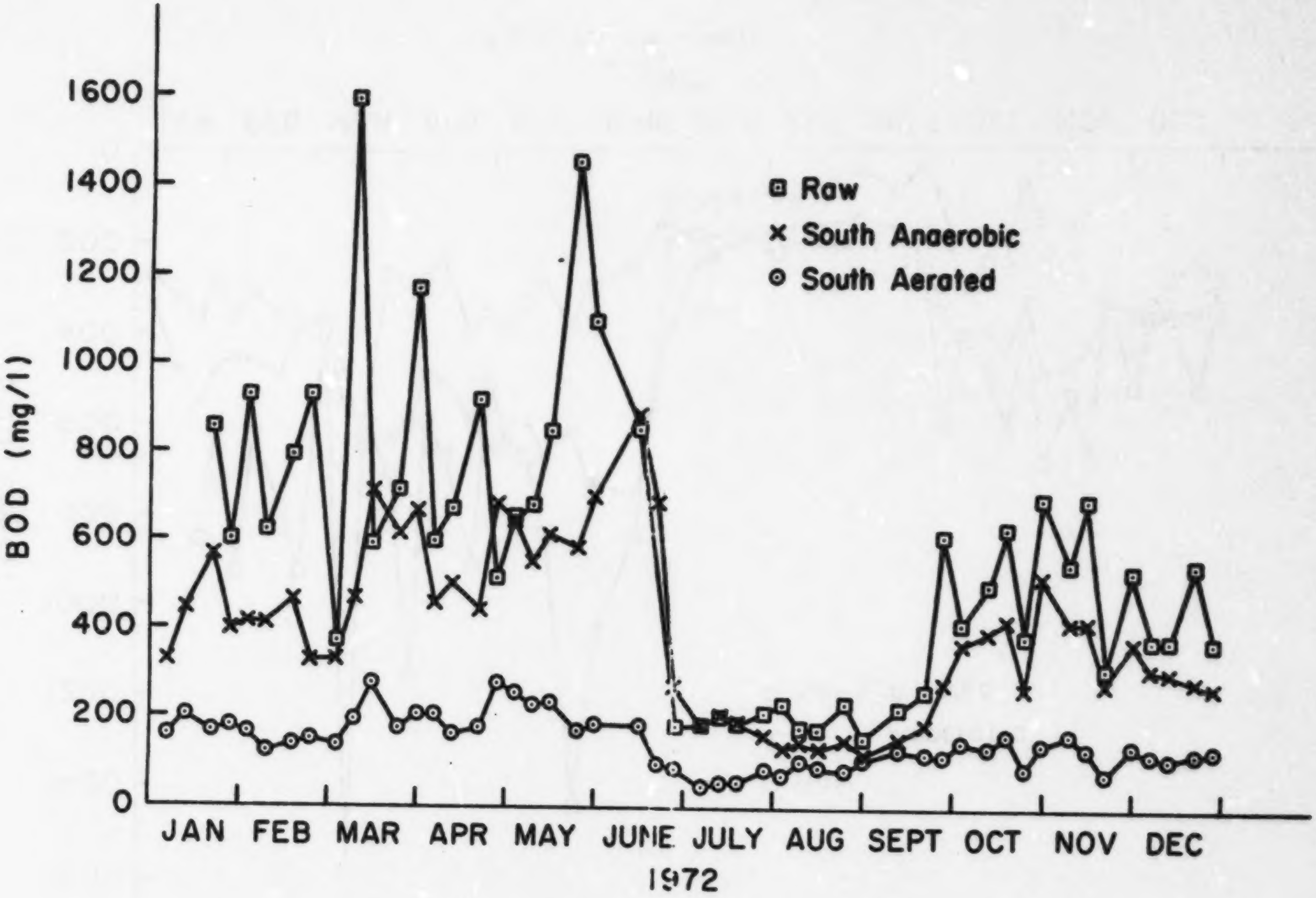

Figure 10. IOD - SOUTH

Table 5. BOD Reduction (%)

Period 1972	NAN	NA	SAN	SA	SAN-SA Series	ALL CELLS
1/15-1/21/72	30.4	53.9	32.0	63.1	74.9	58.5
4/21-4/27/72	36.0	61.3	42.3	59.6	76.7	63.0
5/9-5/15/72	25.9	58.5	26.1	64.2	73.5	57.6
6/6-6/12/72	28.8	77.0	21.0	82.7	86.0	69.4
11/16-11/22/72	19.4	31.6	28.5	70.2	78.7	50.3
12/12-12/18/72	13.3	34.7	30.4	59.8	72.0	46.1
All of 1972*	28.1	57.9	32.6	64.0	75.7	59.3

more reduction during the year than the north cell and this can probably be attributed to higher temperature during cold weather in the south cell. This temperature difference does not exist during the summer when the north anaerobic was about one-half degree higher than the south cell. During this time equal or better reductions were obtained in the north cell which was receiving only one-half as much load as the south cell.

The south aerated cell showed the beneficial effect of being preceded by an anaerobic cell in that the BOD reduction was 6% greater than that in the north aerated while the detention time was only one-half as long. When the two south cells are considered as a unit, thereby making the detention time the same as for the north aerated cell, the BOD reduction is about 18% above that in the north aerated cell. A good share of this increase is, of course, due to the sedimentation occurring in the anaerobic cell. The eventual effect of accumulating sludge in this cell has not been determined at this time.

During the two 7-day runs made during November and December, soluble BOD values were also determined. The north anaerobic cell gave very inconsistent data for these two runs in that one of them indicated an increase in soluble BOD of 21%, and the other an increase of 40%. The south anaerobic values agreed closely with each other, showing an average increase of 17%. In the two aerated cells the results were very nearly identical with a reduction of 90% in soluble BOD observed in the north cell and 87% in the south cell.

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* Preliminary figures

The average ratio of BOD for COD for the year was 0.55 for the raw sewage, 0.68 for each of the anaerobic cells, and C.39 for each aerated cell. These values are nearly identical with values reported by others for secondary treatment of potato processing wastes(5).

In order for aerobic biological treatment to proceed satisfactorily a certain level of inorganic nutrients must be maintained. Commonly quoted minimum figures are a BOD : N : P ratio of 100 : 5 : 1. In this study the ratio for the raw sewage averaged 100 : 9.9 : 4.0, and for the south anaerobic cells the values were 100 : 10.6 : 5.5. Therefore, it would appear that the nutrient level preceding each aerated cell was entirely adequate.

Since the anaerobic cells were not mixed a sludge build-up is occurring in both of these cells. On September 8, 1972, a study was made of the sludge depth in the south anaerobic cell as this cell had been receiving one-half of the total flow. By withdrawing samples at varying depths it was found that a sludge layer about 4 ft. deep existed as the center of the cell. At the side opposite the inlet the depth was only about 2 ft. Eventually it is possible that sludge will have to be withdrawn from the anaerobic cells. The necessity or frequency of this has not as yet been determined.

The treatment provided by the system used during this period had a very beneficial effect on the large stabilization ponds. During the summer of 1971 it was mid-June before the secondary ponds met water quality standard of a BOD of 25 mg/l, or less. The primary lagoons remained above this level until well into July and some odor problems occurred. In the summer of 1972, the large ponds made an early recovery with no odors of any significance. This was a great improvement when it is considered that the pretreatment cells did not become operative until the first of January, while potato processing began in September.

While the pretreatment cells were effective in reducing the odor problem from the main ponds, there was odor emitted from the two uncovered anaerobic cells. Normally, this did not present any problems because of the distant location of the cells from the city. However, if weather and wind conditions were right, an occasional detection of odor occurred within the city.

Generally, the research project operated quite smoothly during 1972 although some nuisance problems occurred. The magnetic flow meters did not give valid readings until the first week in February so the flow for the first month had to be taken from pumping records at the master lift station. At the end of the year the effluent meter which measured all the flow except from the north anaerobic cell was again inoperative.

The most serious interference with the research occurred between 13 May and 19 June. The largest potato processing plant experienced operating difficulties with its waste treatment process and greatly exceeded the organic loading that had been anticipated from them. The 7-day tests taken in April, May and June all gave an average BOD loading of about 35,000 pounds per day, with individual days in excess of

50,000 pounds. With the arrival of warmer weather the biological activity increased to the point where it was impossible to maintain an aerobic condition of the effluent from the two aerated cells. Between 13 May and 19 June the dissolved oxygen content of the effluent leaving the aerated cells was less than 0.25 mg/l, and for most of the period was 0, even with all compressors in operation. When potato processing ceased in mid-June the problem was overcome immediately and did not reoccur again during the year.

During the severe weather of January and February there was some ice build-up on the mixer platforms and shafts. No interruptions of mixer operation occurred, however. All the compositing samplers were housed in insulated shacks equipped with electric heaters but occasionally a stoppage with ice would occur in the sampling line and a grab sample would have to be taken. Fortunately, these situations took place only infrequently. Because of the discharge method the sampler housed over the effluent manhole from the north anaerobic cell was subject to severe corrosion from escaping gases. This sampler could not be left in place except while it was operating which was somewhat inconvenient. Also, electrical connections and contracts would corrode and as a result the sampler would occasionally fail to function.

City personnel responsible for maintenance of the equipment had considerable difficulty with circuit breakers and circuit board vibrations. None of these occurred at such a time that the research project was adversely affected, however.

SUMMARY

This progress report presents data from the first full year of operation of pretreatment cells preceding conventional stabilization ponds at Grand Forks, North Dakota. The waste handled was a combined municipal-industrial waste with main industrial contribution coming from potato processing industries. Data was gathered on anaerobic operation, aerated operation, and anaerobic-aerated series operation for the calendar year of 1972. Composite samples were collected at weekly intervals, with occasional runs of daily sampling for a full week at a time. Although this project is still active and the collection of data continues, the following observations are made on the first year's data:

1. Combined wastes from potato processing and municipal sources contain ample nutrients for successful pretreatment by either aerated or anaerobic-aerated processes.

2. BOD reductions of 50 to 70% can be obtained at temperatures of 5°C, or less, with detention times of from 4 to 7 days in the aerated cells.

3. Aerated or anaerobic-aerated pretreatment produces a poor quality effluent for nitrogen,phosphorous,and suspended solids. Further treatment is necessary to meet surface water quality standards.

4. Periodic removals of sludge may be required from anaerobic pretreatment cells which are not completely mixed. The frequency of such removal is indefinite from the period covered in this report.

5. Winter operation at temperatures of -30°F present no particular problem with diffused aeration and submerged impellers.

6. Anaerobic cells need not be covered or mixed for effective cold weather operation ahead of aerated cells. During warm weather, however, an odor problem may develop.

7. Considerably better pretreatment is obtainable from an anaerobic-aerated series than from aerated treatment alone.

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ACTIVATED SLUDGE - BIO-DISC TREATMENT OF DISTILLERY WASTE***

BY JOHN L. THOMAS* AND DAVID A. SANBORN**

INTRODUCTION

Waste treatment facilities at the Pekin, Illinois, distillery of The American Distilling Company began operation on September 27, 1971. Since that time, facilities have not only provided treatment for plant process wastes, but have also served as a demonstration project with the assistance of an Environmental Protection Agency (EPA) grant.

The objectives of the studies made were to determine the performance, economics, and the design parameters for treating distillery waste. Particular emphasis has been placed on the comparison of the activated sludge and the Bio-Disc (Rotating Biological Contacter) processes.

PRODUCTION PROCESSES

The distillery utilizes processes such as mashing, cooking, fermenting, and distilling. Approximately 12,500 bushels of grain per day are used as the raw material. The initial process step consists of mixing ground grain with water and cooking to produce a mash. The starch content of this mash is then converted to sugar by a malt. The malted mash is fermented and the sugar content is converted to alcohol. Alcohol is recovered from the mash in a primary distillation column. Distillate from this first column is again distilled in a pot still to refine the product. Mash remaining after distillation is centrifuged and dried to produce a high protein feed.

Process wastewater contains non-recoverable grain particles and byproducts such as organic acids, aldehydes, esters, and alcohols. Normal process wastes are increased in flow and strength by the cleaning of grain mixers, cookers, converters, mash coolers, fermenters, stills, centrifuges, and evaporators.

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*** This investigation was supported by funds from the Environmental Protection Agency under Project 12060FL.

WATER AND WASTE SYSTEMS

Water is supplied to the distillery from three sources. A well water system provides process and some cooling water. A river supply is used for other cooling applications. City water is used primarily for domestic and fire protection purposes.

Wastewater discharges include the following:

1. Storm drainage and other uncontaminated waters.
2. Process and sanitary waste.
3. Slightly contaminated wastewater discharging from barometric condensers.

A survey of waste facilities made in 1967 identified 27 sewers from the distillery discharging a mixture of these wastes to the river.

Starting in May, 1967, a systematic program was initiated to identify and isolate process wastewaters. During the summary of 1969, a sewer separation program was completed in which all high strength process wastewaters were routed to a pumping station which directed this flow to the river. Later, this pumping station was utilized for discharging the wastewater to the treatment plant. High volume flows from the barometric condensers which contain relatively low concentrations of BOD were also isolated and combined in a separate trunk sewer for direct discharge to the river.

After completion of the sewer separation project, the process wastewater stream was continually monitored to establish wastewater characteristics and flow variations. These data were to serve as a basis for treatment plant design.

In the initial assessment of the treatment requirements, it was planned to treat the process waste stream and then mix this treated water with the high volume flows from the barometric condensers. This mixture would yield a total waste flow to the river having a BOD_5 content of less than 30 mg/l. Subsequent modification of regulatory agency standards required change to this approach. These revised regulations prohibited the blending of cooling water with waste. Also, the goal for effluent quality was revised to permit only 20 mg/l of BOD_5.

Sampling, gaging, and testing prior to treatment plant design indicated that flow, BOD, and suspended solids varied quite widely on both a daily and hourly basis. These variations are a function of production process and operations being performed. An operation such as mashing may occur two, three, or four days per week. Distilling may be performed on other days. Some days, both of these processes are used. Equipment cleaning also affects the total load by imposing periodic additions to the normal process loads. Fermenter washing and pot still cleanout are typical of such operations.

A complete analysis of hourly waste strength variation was not made. However, limited hourly tests of BOD_5 indicate a variance from less than 200 mg/l to over 10,000 mg/l. It was projected that daily loads would exceed a level of 3,200 pounds of BOD_5 about 20 percent of the time.

The pH of the waste is increased periodically by the presence of alkaline cleaning chemicals. Data indicated that pH of the processed waste flow may vary from a low of 2 to as high as 13. Large flows of waste bearing condensate during periods of evaporator operation significantly increase the total process waste temperature. Temperature of the waste varied from 50 F to over 150 F.

Concentrations of nitrogen and phosphorous were low enough to indicate the need for the addition of these nutrients for satisfactory biological treatment.

Variation of these waste parameters directly influenced the design philosophy for the treatment facility.

After the waste treatment plant was placed in operation, collection of raw waste data continued. These data are described later herein along with treatment plant operating characteristics.

LABORATORY STUDY

In 1968, laboratory studies were initiated to determine factors affecting treatment plant performance. These studies indicated that the waste was amenable to biological treatment and that the activated sludge process was an effective treatment for distillery wastewaters. It was also determined that consideration must be given to pH, temperature, and nutrients. In the aeration basin, pH must be maintained within the range of 5.0 to 9.0, temperature must be maintained at less than 100 F and some supplemental nutrient addition would be required.

PLANT ARRANGEMENT

Because of the relatively low level of suspended solids anticipated, primary sedimentation of the waste was not included as a unit operation in the treatment plant design. However, a grit chamber was included as an initial step to remove heavy particulate matter.

The selection of the configuration and size of biological treatment equipment was based on several considerations:

1. The Bio Disc was included to evaluate its performance for treating distillery waste.
2. An equalization basin was incorporated to minimize the effect of waste load variation. This was required particularly for the Bio Disc because of its plug-flow characteristics.
3. One aeration basin for the activated sludge process was sized to be capable of treating approximately the same flow as the Bio Disc.
4. Facilities were arranged to maintain a relatively constant flow through the Bio Disc and the companion aeration basin to minimize the effect of flow variation on equipment performance.

The plant configuration selected included four biological treatment lines. The Bio Disc was sized to treat one-fourth of the plant waste while each of three activated sludge lines were sized to treat one-third of the plant waste. It was planned that the Bio Disc and one activated sludge line would each treat equal flows during many phases of the test period. Any additional flow would be delivered to other two aeration basins.

The Bio Disc was designed as a six stage unit with an intermediate settling tank after the third stage. The manufacturer designed a system to provide 90 percent reduction of BOD and suspended solids at an average flow rate of 120,000 gpd and a BOD loading of 800 pounds per day. These waste characteristics result in an organic loading of 17.8 pounds of BOD_5 per 1,000 square feet of biological surface. To minimize the effect of the continuing variations in wastewater flow, pH, temperature, and strength an equalization basin preceding the Bio Disc was designed with a detention time of eight hours at a flow of 132,000 gpd.

The activated sludge aeration basin was designed for solids retention time of approximately 30 days at average flow rates. This resulted in a 33-hour hydraulic detention period at an average flow of 177,000 gpd and an average organic loading of 33 pounds BOD_5 per 1,000 cubic feet per day. The objective was to achieve some measure of aerobic digestion and provide sufficient aeration volume to dampen out the effect of large hourly variations in wastewater flow, temperature, pH, and strength.

PROCESS FLOW PATTERN

Figure 1 is a plant flow schematic which illustrates the relationships of the various unit operations in the treatment plant.

Untreated waste is collected in the process sewer system and routed to the main pump station. The flow is pumped through a grit chamber where large particulate matter is removed and required supplemental nutrients (nitrogen and phosphorus) are added.

The next unit in the flow sequence is an, equalization basin and flow splitter which is designed to serve two functions:

1. Provide adequate volume for buffering peaks in temperature and pH for that portion of waste flowing to the Bio Disc unit.
2. Provide a means for dividing total waste flow to the four process treatment lines.

In the basic parallel flow sequence, a constant 25 percent of the plant design waste flow (133,000 gpd) was directed to the Bio Disc unit and another 25 percent was routed to Aeration Basin No. 3. The balance of the waste flow was treated in Aeration Basins 1 and 2.

The Bio Disc unit consists of a series of closely spaced discs mounted on a horizontal shaft. Discs are submerged in the wastewater to just below the shaft level in a tank with the bottom formed in a cylindrical shape slightly larger than the discs. Rotation of the shaft alternately exposes disc surface area to the wastewater and to the atmosphere. The discs thus serve both as media for growth of a biological slime and as an aeration device. Intermediate settling is provided between stages of the Bio Disc. Sludge removed at this point is normally discharged to Aeration Basin No. 2 for further stabilization.

Treatment Plant Schematic

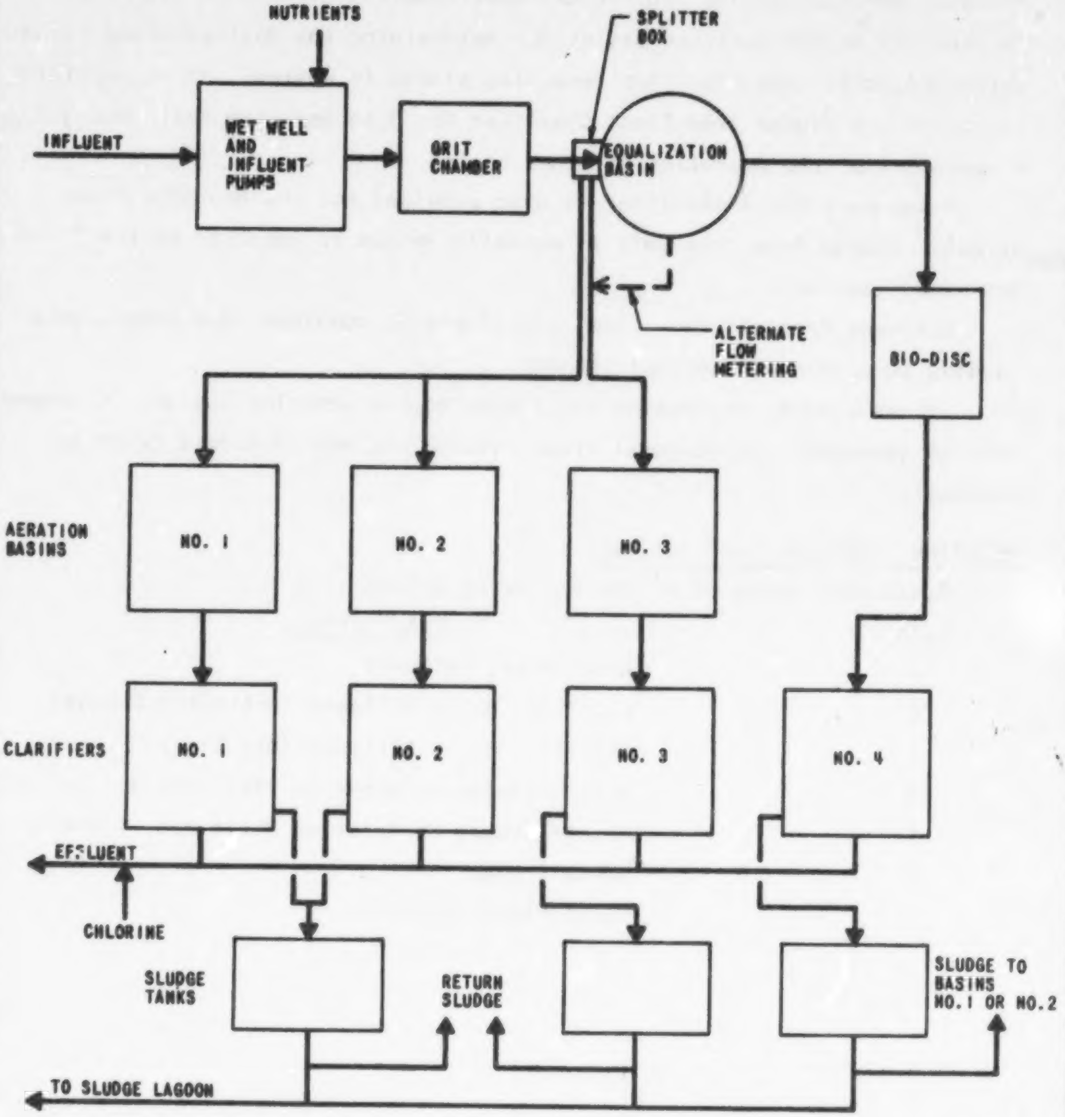
NUTRIENTS
SPLITTER BOX
INFLUENT
WET WELL AND INFLUENT PUMPS
GRIT CHAMBER
EQUALIZATION BASIN
ALTERNATE FLOW METERING
BIO-DISC
AERATION BASINS
NO. 1
NO. 2
NO. 3
CLARIFIERS
NO. 1
NO. 2
NO. 3
NO. 4
EFFLUENT
CHLORINE
SLUDGE TANKS
RETURN SLUDGE
SLUDGE TO BASINS NO. 1 OR NO. 2
TO SLUDGE LAGOON

Figure 1

The Bio Disc unit is housed in 16 feet by 64 feet concrete block building.

Three identically sized aeration basins operating as complete mix activated sludge units are provided for contact between the active microorganisms and the waste materials. A separate final clarifier is provided for each aeration basin. Sufficient underflow from the final clarifiers is returned to the aeration basins for maintaining the desired mixed liquor suspended solids content. The remaining sludge is wasted. It is possible to return the sludge from Final Clarifier No. 3 to Aeration Basin No. 3 independent of the operation of other basins.

A separate final clarifier is also provided for the Bio-Disc flow stream. Sludge from this unit is normally routed to Aeration Basins 1 and 2 for stabilization.

Effluent from all four final clarifiers is combined in a single sewer leading to a chlorine contact chamber.

Excess sludge, not needed for return to the aeration basins, is pumped onto an abandoned ash disposal area. Sludge was not thickened prior to disposal.

METERING, SAMPLING, AND TESTING

Flows were measured at the following points:

Point	Description
A	Total Plant Influent
B	Clarifier No. 3 Effluent (Activated Sludge)
C	Clarifier No. 4 Effluent (Bio Disc)
D	Return Sludge to Aeration Basin No. 3
E	Return Sludge to Aeration Basin Nos. 1 and 2
F	Waste Sludge
G	Total Plant Effluent

Twenty-four hour composite samples were routinely collected from Points A, B, C, and G for a complete analysis. Solids and COD tests were made daily while BOD, nitrogen, and phosphate tests were made twice weekly.

All samples were analyzed at the American Distilling Company laboratory. All analyses were conducted in accordance with procedures described in the 13th edition of Standard Methods.

OPERATIONAL PROCEDURES

In order to achieve the stated objectives of the research project, the study period was divided into stages of different operational patterns. During the total period of the study from the beginning on September 27, 1971, to the completion on December 24, 1972, 12 operational stages were evaluated. The original operational plan was modified considerably as the results from each stage were obtained.

Table 1 summarizes the operational conditions for each stage. A brief description of each stage is presented below.

Stage 1 - The purpose of this stage was to establish an acclimated population of biological organisms for both the activated sludge and Bio Disc Processes. It was also to provide an opportunity to determine and correct any mechanical operational problems.

Operational problems with the stationary aerators, septic conditions in the equalization basin, and apparent overloading of the Bio Disc unit extended this stage until February 6, 1972, for a total period of 19 weeks. Initially, flow to both the Bio Disc and Aeration Basin No. 3 were routed through the Equalization Basin. This operating pattern was selected on the basis that both test lines should receive waste of the same quality.

At the start of this stage, flow to the Bio Disc and Aeration Basin No. 3 was to be 133,000 gpd (25 percent of the plant design flow) each. Because of inadequate treatment by the Bio Disc, flows were reduced to this unit in November to about 50,000 gpd. In January, in order to reduce the effect of sudden peaks in raw wastewater temperature and pH, only flow to the Bio Disc was routed through the Equalization Basin.

TABLE 1

PLANNED AND ACTUAL OPERATING PATTERNS

Stage	1	2	3	3A	4	5	6	7	8	9	10	11	12
BIO DISC													
Flow, 1,000 gpd													
Planned	--	60	60	45	45	45	45	45	90	130	64	72	265
Actual													
Average	57	63	69	45	49	45	48	45	71	114	55	65	188
High	175	74	78	61	65	60	72	59	86	140	132	74	279
Low	5	43	50	34	25	18	15	10	27	36	28	27	38
ACTIVATED SLUDGE													
Flow, 1,000 gpd													
Planned	133	133	133	133	133	133	80	45	90	130	185	212	265
Actual													
Average	92	135	156	123	114	148	79	50	78	118	170	195	201
High	183	162	175	147	155	103	150	63	92	161	196	222	279
Low	11	72	100	69	33	35	27	33	33	86	95	86	82
MLSS, mg/l													
Planned	--	1250	2500	3500	3500	4500	4500	4000	4500	4500	4000	4000	4000
Actual													
Average	--	1670	2400	2200	3615	4300	3660	3960	4200	4240	4860	4025	3285
High	--	2110	3285	2940	5175	4615	4755	5785	5985	5255	6935	5605	4815
Low	--	1070	1230	1650	2800	3870	2675	2390	2750	2935	3685	2385	1210

Stage 2 - This stage extended from February 7 to February 20, for a period of two weeks. The plan was to hold the average flow to the Bio Disc at 60,000 gpd (11 percent of total plant design flow) and the flow to Aeration Basin No. 3 to 133,000 gpd. Actual flow to the Bio Disc averaged 63,000 gpd while flow to Aeration Basin No. 3 averaged 135,000 gpd. Scheduled MLSS concentration in the aeration basin was 1,250 mg/l, but rapid bio-mass growth resulted in an average MLSS of 1,670 mg/l during this stage.

Stage 3 - Stage 3 extended from February 21 to March 12 for a period of three weeks, and was divided into two phases. The first week, the average flow to the Bio Disc was 69,000 gpd, but BOD removal was so poor that flows to the Bio Disc were reduced to 45,000 gpd during the last two weeks (Stage 3A).

The scheduled average flow to Aeration Basin No. 3 was again 133,000 gpd but actually averaged 156,000 gpd for the first week and 123,000 gpd during the last two weeks. The target MLSS level was 2,500 mg/l. Actual MLSS concentrations averaged 2,400 mg/l for the first week and 2,200 mg/l for the last two weeks.

Stage 4 - The goal of Stage 4, which began on March 13 and ended on April 2 for a total of three weeks, was to hold the flow to Aeration Basin No. 3 at 133,000 gpd and the MLSS concentration at 3,500 mg/l. Flows to the Bio Disc were scheduled at 45,000 gpd.

The actual average flow to the Bio Disc was 49,000 gpd. Aeration Basin No. 3 received an average flow of 114,000 gpd and MLSS concentrations averaged 3,615 mg/l.

The septicity of the wastewater influent to the Bio Disc from the Equalization Basin was considered to be a contributing factor in the continuing low BOD removal rates. Therefore, work was initiated on the design and installation of an aeration system for the Equalization Basin.

Stage 5 - This stage began on April 3 and ended on April 16 for a total period of two weeks. The scheduled flow to the Bio Disc was 45,000 gpd which was the actual average flow for the period. Scheduled flow to Aeration Basin No. 3 was 133,000 gpd with MLSS concentrations at 4,500 mg/l. Actual average flow and MLSS were 103,000 gpd and 4,294 mg/l, respectively.

It was initially anticipated that after Stage 5, a MLSS level would be selected at which optimum BOD removals occurred. Since BOD removals were excellent at all studies MLSS concentrations, there was no apparent optimal level. Therefore, it was decided to maintain a MLSS concentration in the 3,500 to 4,500 mg/l range for future stages. It was felt that this level would provide average protection against moderate shock loads. Flows to the Bio Disc would be continued at 45,000 gpd until the aeration system was installed in the equalization basin.

Stage 6 - This stage lasted four weeks, from April 17 to May 14, until septic conditions were reduced in the Equalization Basin. The schedule was to operate Aeration Basin No. 3 at an average flow of 80,000 gpd (15 percent of total plant design flow) and the Bio Disc at 45,000 gpd.

Actual flow to Aeration Basin No. 3 averaged 79,000 gpd and MLSS averaged 3,360 mg/l. Actual flow to the Bio Disc averaged 48,000 gpd.

On May 11, the Equalization Basin aeration system was put into operation. By May 15, septic conditions in the Basin had been substantially reduced, although no measurable DO was present in the effluent.

In order that the activated sludge and Bio Disc operations be comparable, it was decided in the next stage to again route all flow to Aeration Basin No. 3 through the Equalization Basin. In order to not overload the Bio Disc, about 100,000 gpd of raw wastewater would be routed to the Equalization Basin. About half of the flow would go to each process.

Stage 7 - This stage began on May 15 and ended on June 18 for a period of five weeks. Flows to Aeration Basin No. 3 averaged 50,000 gpd and MLSS concentrations averaged 4,000 mg/l. The Bio Disc received an average flow of 45,000 gpd.

Stage 8 - In this stage, it was decided to increase the flows to each of the processes to 90,000 gpd, and again route the total flow of 180,000 gpd through the Equalization Basin. MLSS concentrations in Aeration Basin No. 3 was scheduled for 4,000 mg/l.

This stage began on June 19 and ended on July 16 when the distillery began its annual shutdown for vacations and maintenance. During this four-week period, the average flow to Aeration Basin No. 3 averaged 78,000 gpd and MLSS concentrations averaged 4,200 mg/l. The Bio Disc received an average flow of 71,000 gpd.

At the end of this stage, it was concluded that the activated sludge process should receive hydraulic loads of progressively greater magnitude in the stages following the annual distillery shutdown period. Since the activated sludge process showed no recognizable sensitivity to sudden changes in influent pH and temperature, it was decided to route only the Bio Disc influent through the Equalization Basin in future stages.

Stage 9 - This stage began September 11 and ended on October 1 for a period of three weeks. Scheduled flows to both test lines were 130,000 gpd. The average flow to Aeration Tank No. 3 was 118,000 gpd and the average MLSS concentration was 4,237 mg/l. Flow to the Bio Disc averaged 114,000 gpd.

Stage 10 - This stage began on October 30 and ended on November 26, for a period of four weeks. Scheduled flow to Aeration Basin No. 3 was 185,000 gpd. Actual flow averaged 170,000 gpd and MLSS averaged 4,860 mg/l.

Scheduled flow to the Bio Disc was 64,000 gpd. The actual flow averaged 55,000 gpd. Effluent from the Bio Disc final settling tank during the first week of this stage was so poor that it was returned to Aeration Basin Nos. 1 and 2. After the first week, the Bio Disc effluent quality improved considerably and this practice was stopped. During the last week of this phase, the first stage of the Bio Disc was inoperable because of mechanical problems.

Stage 11 - This stage began on October 30 and ended on November 26 for a length of four weeks. Average flow to Aeration Basin No. 3 was scheduled for 212,000 gpd but actually averaged 195,000 gpd. MLSS averaged 4,025 mg/l.

Average Bio Disc flow was scheduled for 72,000 gpd but actually averaged 65,000 gpd. Effluent from Final Settling Tank No. 4 was returned to Aeration Basin Nos. 1 and 2 during one week because of poor quality.

Stage 12 - This stage was the last four weeks of the project, from November 27 to December 24. During this period, the Bio Disc and activated sludge processes were operated in series. Flow from the Equalization Basin went first through the Bio Disc and then directly to Aeration Basin No. 3. Mixed liquor from Aeration Basin No. 3 was proportioned between Clarifier Nos. 3 and 4 to achieve equal surface settling rates in each unit.

Necessary piping changes were made during the first week of the stage. Flows during the last three weeks averaged 224,000 gpd, while MLSS in Aeration Basin No. 3 averaged 3,285 mg/l.

START-UP ADJUSTMENTS AND OPERATIONAL PROBLEMS

After plant operation began in late September, 1971, Stage 1 operating procedures were followed through February 6. During this period, a biological mass capable of treating the distillery wastewaters developed and necessary modifications to some of the equipment was begun.

Nutrient Addition - As previously indicated, nitrogen and phosphorous were to be added to the wastewater to provide necessary nutrients for biological growth. Nitrogen and phosphorous were to be added equal to 5 percent and 1 percent of the BOD_5, respectively. Anhydrous ammonia injected as a water solution was added to provide nitrogen and phosphorous was added as triple superphosphate.

Both nutrient supply systems developed problems with plugging of supply piping. This was solved in the phosphate system by:

1. Mixer modification in the supply tank to provide better dispersion of the poorly soluble triple superphosphate.
2. Screening of the phosphate suspension.
3. Use of supplemental carriage water to dilute the phosphate suspension.

The nitrogen system originally relied upon untreated well water as a carrier of the ammonia nitrogen to the wet well. The high pH of the ammonia solution resulted in precipitation of calcium and possibly some magnesium present in the well water. Scale formations completely plugged the ejector in only a few hours. This problem was minimized by substituting mixed liquor from Aeration Basin No. 2 for the well water as the carriage liquid.

Due to operational problems as well as some initial analytical errors, nutrients were often below requirements during the first several months of operation. By the time Stage 2 began on February 4, the phosphate problems had been corrected, although a satisfactory nitrogen delivery system was not completed until Stage 4 in late March.

Grit Removal - The amount of particulate material in the waste far surpassed original design estimates. So much so, that a chute to transport the materials to the ground replaced the original reception barrel. Also, some freezing of the solids in the grit chute was experienced.

Mechanical Aerators - The pier-mounted mechanical aerators underwent numerous mechanical modifications. The initial units exhibited excessive vibrations that resulted in mechanical failure. In November, the mechanical aerators were replaced by temporary floating units while repairs were made to the mechanical units. While the pier-mounted aerators were all operating again by February 4, in-place modifications were not complete until April.

Low DO levels were frequently experienced in Aeration Basin No. 3. DO levels often dropped to 0 mg/l.

Flow Rates - It was difficult to control flow rates to Aeration Basin No. 3, because of the constant-speed raw wastewater pumps and the problems encountered in attempting to manually adjust the flow with an on-off pumping cycle serving a continually varying wet well influent flow.

Equalization Basin - The longer detention periods of waste in the Equalization Basin due to lower flow rates through the Bio Disc resulted in septic conditions. This led to the installation of an aeration system in the Basin that was put into operation on May 11.

Bio Disc - The Bio Disc experienced numerous mechanical failures, particularly in the intermediate settling tank.

Final Settling Tanks - Several days of icing were experienced during the coldest weather, but in general the final clarifiers were free of mechanical problems.

Sludge Disposal - The waste activated and Bio Disc sludge did not dewater satisfactorily in the sludge disposal area. Ponds of water were nearly always present. Periods of very high SVI's were experienced with the MLSS. Possible reasons for these two conditions are explained later in the report.

SYSTEM LOAD

The wide variation in wastewater flow, strength, pH, and temperature resulted in wide variations in loadings to Treatment Line Nos. 3 and 4 during the various operational stages as shown in Table 1.

Results shown based on a five-day operational week from Monday through Friday. Weekend flows and wastewater characteristics have not been subjected to a detailed study. However, loads during weekends are generally considerably lower than weekday loads.

In an attempt to develop a technique for prediction of BOD loadings from distillery operations a relationship between BOD_5 and bushels of grain mashed was investigated. Grain is not mashed every day and other plant production processes in use vary from day to day. However, a one week period represents a normal recurring cycle and it was believed reasonable that a relationship between bushels of grain mashed weekly and weekly total pounds of BOD_5 could be developed. Data is shown on Figure 2.

Two curves are also shown. The equations of these curves are as follows:

Curve A: $BOD_5 = 0.256\ B$

Curve B: $BOD_5 = 7{,}982 + 0.177\ B$

where

BOD = Total weekly raw wastewater BOD_5, lb.

B = Grain mashed weekly, bushels.

The equation for Curve A is derived from the design basis of 3,200 lb of BOD_5 produced from a daily grain mash of 12,500 bushels.

The equation for Curve B is obtained from a linear regression analysis to determine the line of best fit. A correlation coefficient of 0.43 indicates a poor fit of the curve to the data.

It was concluded that weekly loadings of BOD_5 cannot be accurately predicted from bushels of grain mashed.

Figure 3 shows the frequency of daily BOD_5 loadings. The data analyzed the daily BOD_5 load was less than the design load of 3,200 pounds, 76 percent of the time.

BOD_5:COD RELATIONSHIP

Nutrients were added to the wastewater in the weight ratio of BOD_5: Nitrogen: Phosphorous of 100:5:1. In order to adjust the nutrient feed to BOD levels an immediate analysis for BOD is desirable. Since the BOD_5

Relation Of Raw Waste BOD_5 To Grain Mashed

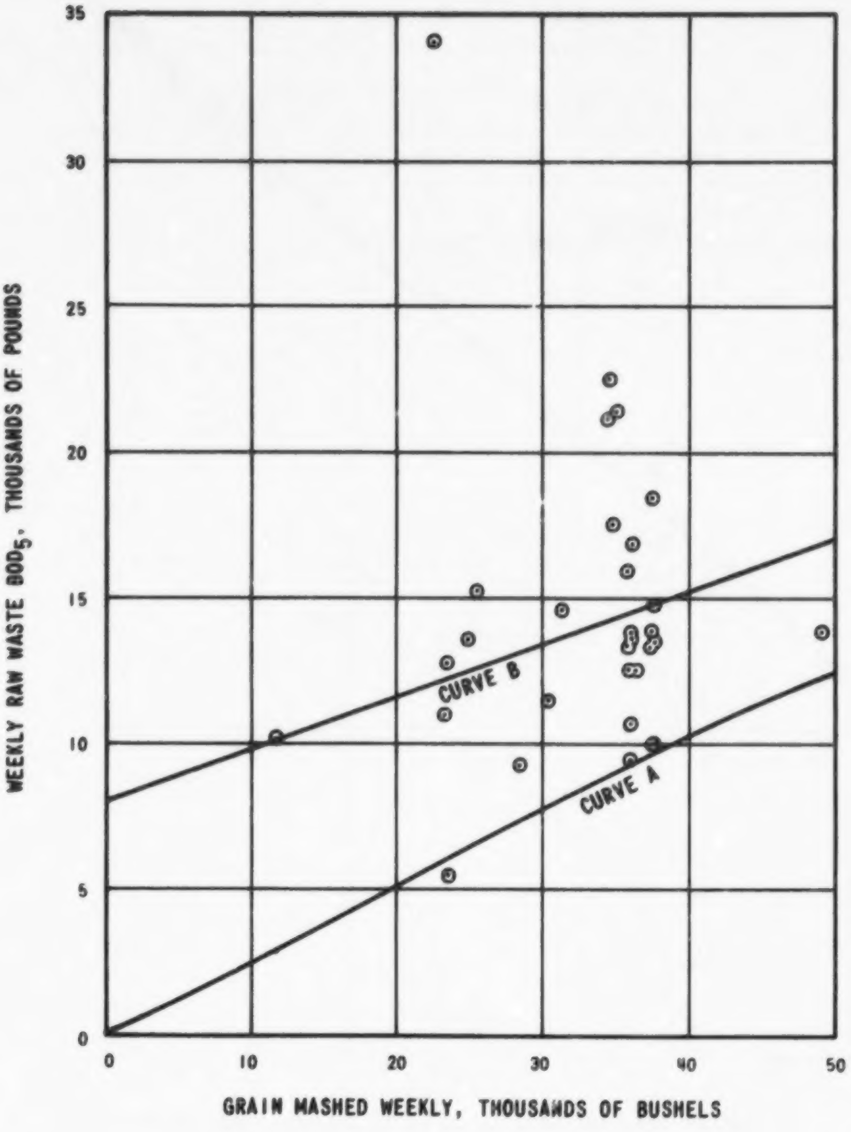

Figure 2

BOD$_5$ Load Frequency Treatment Plant Influent

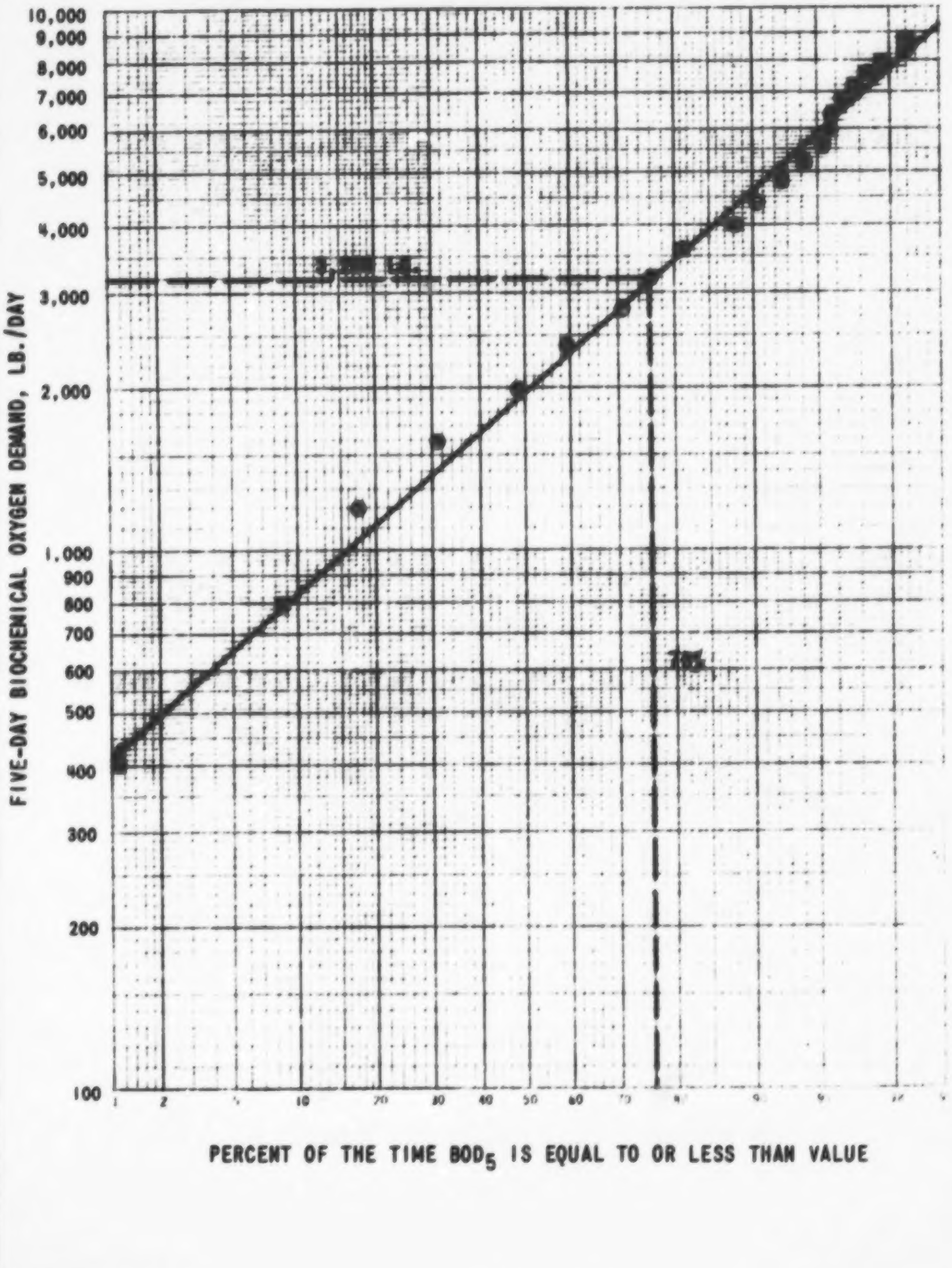

Figure 3

test takes five days for completion results cannot be used to adjust nutrient feed rates to correspond to variations in BOD_5.

At some wastewater treatment plants, the hourly and daily fluctuations in BOD are minimal or exhibit a rather predictable pattern. At this plant the BOD_5 loadings are not only highly variable, but do not show any predictable pattern. Without reliable information as to likely BOD_5 loads for a given day or hour, the plant operator has had to set nutrient feed rates at arbitrarily high levels, so that enough nitrogen and phosphorus will be available during periods of high loads. This has led to unnecessarily high BOD_5:N:P ratios during days of low loads.

The standard COD test takes about three hours for completion and, therefore, could be of considerable more value in adjusting nutrient feed rates if a relationship between BOD_5 and COD is established. In addition, there are automatic COD analyzers on the market that can give COD analyses in a matter of minutes.

Therefore, a correlation between influent BOD_5 and COD was sought. The relationship developed is shown in Figure 4.

ACTIVATED SLUDGE PERFORMANCE

Waste loads to the activated sludge process varied widely from day to day and hour to hour on a daily basis. Variance on a daily basis was from 40 to over 7,000 pounds of BOD_5. The response of the system to such variations in load has generally been good. Effluent BOD_5 was normally measured only on Tuesday's and Thursday's so removal percentages were available twice per week on this basis. However, COD values were determined daily on composite samples. Average BOD_5 removals shown on Table 2 were well in excess of 90 percent. In an assessment of all the data, only five or six values were less than this level.

During several stages of the study, varying quantities of the flow to Aeration Basin No. 3 have passed through the Equalization Basin. As expected, such equalization had no apparent effect in treatment performance.

The response of the activated sludge system to large shock loads was demonstrated on two occasions. Early in March, a BOD_5 load of 3,000 pounds

COD And Corresponding BOD_5 Treatment Line No 3 Influent

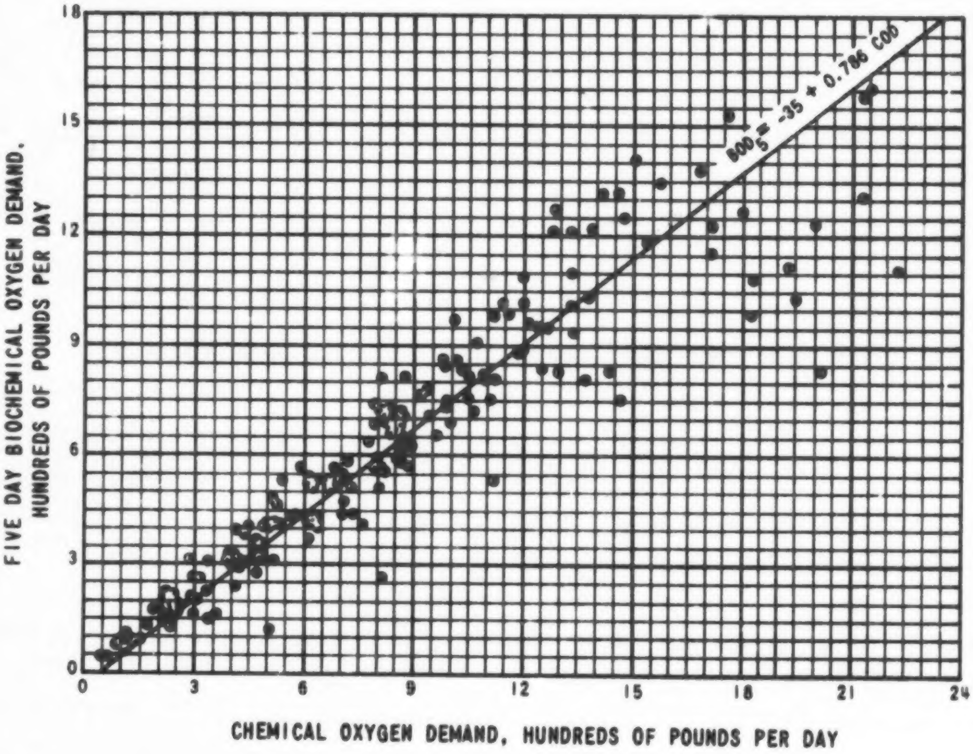

Figure 4

TABLE 2

PERFORMANCE DATA - ACTIVATED SLUDGE*

	Stage	1	2	3	3A	4	5	6	7	8	9	10	11	12**
INFLUENT BOD$_5$														
Concentration, mg/l	Low	165	605	290	460	425	558	355	121	690	403	248	296	360
	High	1,470	1,080	620	1,280	2,320	1,300	1,390	1,800	9,680	1,640	1,280	1,300	4,125
	Average	589	775	455	793	949	1,021	747	1,004	1,992	936	709	593	990
Weight, lb/day	Low	41	509	414	311	411	380	215	52.5	295	445	360	222	135
	High	1,410	1,190	859	1,100	3,000	1,610	1,160	840	7,030	1,580	1,725	2,265	7,610
	Average	476	911	637	798	1,018	787	486	414	1,340	916	1,000	1,020	1,670
EFFLUENT BOD$_5$														
Concentration, mg/l	Low	9	10	20	7	18	27	7	7	20	11	9	12	14
	High	62	85	21	24	108	37	42	129	39	26	29	25	605
	Average	29	38	21	18	52	32	20	40	27	20	21	18	122
Weight, lb/day	Low	3.5	12.5	29.2	8.3	21.0	7.9	3.8	2.6	12.4	11.9	15	21	19
	High	67.8	88.0	30.0	27.0	118.0	44.8	33.3	50.6	29.0	28.2	45	44	1,410
	Average	20.7	42.9	29.6	19.7	58.6	30.4	14.1	16.7	18.3	20.3	32	31	254
AVERAGE BOD$_5$ REMOVAL, %		93.9	96.1	92.8	97.9	93.7	96.6	97.6	95.0	97.9	97.6	96.9	96.7	89.9

* 24-hour composite sample.
** Bio-Disc in series with activated sludge.

entered Aeration Basin No. 3. On that day, no BOD_5 sample was taken. COD of the waste was reduced nearly 95 percent from 2,730 to 149 mg/l. BOD_5 samples taken the following day indicated reduction from 935 to 108 mg/l. This is 88 percent removal. Only 30 mg/l of effluent BOD_5 was soluble. In mid-July, Aeration Basin No. 3 received a load of approximately 7,000 pounds of BOD_5 on one day. BOD_5 determinations were not made on that day, but COD was reduced 99 percent from 9,635 to 129 mg/l. The following day when BOD_5 tests were made, reduction was 97 percent from 1,650 to 65 mg/l. On the basis of these and other experiences with less severe shock loading, it is concluded that the activated sludge process as designed has the ability to withstand such peak loadings without upset and still provide removal for large quantities of BOD_5

One of the major concerns of the research project was to determine the range MLSS concentrations which resulted in optimum BOD_5 removal. It is concluded from the present data that good removals can be obtained at any level of MLSS between 2,400 to 4,500 mg/l.

A related operating factor studied was the F/M ratio expressed as pounds of influent BOD_5 per pound of MLVSS under aeration. Although there is a lack of data at the higher F/M values, removals rate appear generally satisfactory at all levels from 0.01 to 0.65.

Dissolved oxygen levels in Aeration Basin No. 3 often drop to essentially zero. This would naturally be expected on those days with high loadings. However, it is quite possible that some of this problem may be associated with aerator performance and that actual alpha and beta factors are lower than that used for design purposes. Nevertheless, such oxygen deficiencies did not appear to seriously lower removal efficiencies.

Sludge settleability and drainability have not been good. The sludge-volume index has frequently exceeded 200 ml/g. Since many of the F/M ratios were low, this could account for a part of this problem. Most polyelectrolytes and metal coagulants tested to date have not been effective in providing clarification of the effluent. However, further work is proceeding along these lines with some promise being shown.

BIO-DISC PERFORMANCE

Early in Stage 1, it became apparent that the Bio Disc would not be able to treat its design flow of 120,000 gpd without some modifications of the treatment process. Data on performance are shown on Table 3.

It was believed that two factors were the prime cause of poor performance. The first was the wide fluctuation in raw waste temperature and pH. These variations were not being adequately minimized by the Equalization Basin. The second factor was that the flow rate was apparently higher than Bio Disc capacity. It was determined that the answer to both of these problems was to reduce the volume of flow through the Equalization Basin to the Bio Disc. In Stages 3 to 6, all flow to the Bio Disc was routed through the Equalization Basin. Detention time was approximately doubled. This improved temperature and pH control, but led to septic conditions in the Equalization Basin. The septic condition of the waste flowing to the Bio Disc was believed to be reducing normal biological activity. By Stage 7, an aeration system had been introduced for the Equalization Basin. After several days, the septic conditions were eliminated. However, little or no dissolved oxygen was present in the Equalization Basin discharge. Successive attempts in later stages to increase Bio Disc hydraulic loading resulted in poor removal performance. This indicates that the Bio Disc capacity is quite sensitive to hydraulic loading.

CONCLUSIONS

Based on the studies made, the following conclusions are reached:

1. Flow and strength of waste from a distillery can vary quite widely. For satisfactory characterization, a well-planned gaging and sampling program is required.
2. Design philosophy must recognize the variable nature of the waste by providing waste equalization capacity. This requirement can be met by separate equalization tanks or by added detention periods in such plant components as aeration basins. The Bio Disc or any plug-flow or short detention process will require separate equalization facilities.

TABLE 3
PERFORMANCE DATA - BIO-DISC

INFLUENT BOD$_5$	Stage	1	2	3	3A	4	5	6	7	8	9	10	11
Concentration, mg/l	Low	165	605	290	460	425	558	355	121	690	403	248	296
	High	1,470	1,080	620	1,280	2,320	1,300	1,390	1,800	9,680	1,640	1,280	1,330
	Average	589	775	455	793	949	1,021	747	1,004	1,992	936	709	593
Weight, lb/day	Low	21	254	189	134	170	152	95	40	240	445	118	67
	High	1,460	658	347	456	1,050	530	695	720	6,140	1,535	755	744
	Average	289	427	268	297	398	357	294	378	1,201	881	320	342
EFFLUENT BOD$_5$													
Concentration, mg/l	Low	35	170	174	51	99	210	44	23	53	398	16	78
	High	1,160	277	270	285	174	264	326	143	840	2,240	246	335
	Average	251	216	222	173	138	243	108	67	269	909	106	149
Weight, lb/day	Low	12	84	113	26	48	71	13	3	28	399	8	46
	High	385	164	167	131	77	105	195	70	435	1,755	103	187
	Average	116	120	140	78	62	94	51	28	167	860	45	87
REMOVAL RATE, BOD$_5$, %	Low	<0†	68.5	40.0	55.7	70.5	57.2	51.3	76.0	49.1	<0†	40.0	74.3
	High	92.6	78.8	40.0	94.3	87.5	81.7	94.3	96.9	95.6	62.4	97.3	87.4
	Average	70.1	75.1	40.0	75.4	82.7	74.8	86.1	91.6	80.8	--	83.4	78.7

† Total pounds of BOD$_5$ in effluent higher than total pounds in influent.

3. The activated sludge process is an effective means of reducing BOD_5 of distillery waste to a low level. Normally removals in excess of 90 percent can be accomplished. Wide fluctuations in temperature, pH, and loading do not affect performance.
4. Some further study of aeration equipment application is desirable for this facility to maximize performance.
5. Additional work is required toward production of a better settling and more drainable sludge. Recent use of polyelectrolytes has shown some promise.
6. Bio Disc performance is not as satisfactory as that anticipated. This is undoubtedly due to wide variation in waste characteristics. Pre-settling and long equalization periods may prove advantageous. It should be emphasized that smaller space requirements, lower power consumption, and other similar advantages of the Bio Disc indicate that this process with adequate pre-treatment modifications may still hold promise for economical treatment.

LOADING CHARACTERISTICS AFFECTING THE PERFORMANCE OF A LABORATORY DAIRY WASTE WATER TREATMENT SYSTEM

by

Dr. James V. Chambers*, and Dr. W. James Harper**

INTRODUCTION

As a result of much early work with dilute skimmilk as the model of dairy waste water, most people have come to accept milk wastes as "completely compatible with municipal wastes" and "easy to treat by biological means". These views have held in spite of continuous problems encountered over the years by dairy plants which operated their own treatment facilities. Two factors that were ignored in much of the early work on dairy wastes was the effect of loading of organic solids above 1000 ppm BOD and the presence of materials other than skimmilk in the waste water which might affect the performance of the biological treatment system. Harper, et al.(11) reported dairy food plant waste waters with BOD_5 strengths in excess of 3000 ppm as being rather common. They also found surfactants in these waste waters at concentrations that would be expected to affect the oxygen diffusion characteristics of the treatment system and which might change the microbiological character of the waste water and subsequent performance of biological treatment systems.

Adamse(1,2) showed that the microflora in the activated sludge system of dairy waste water treatment was slow to adapt to this waste and that the composition of the waste water could affect the types of microflora which developed. He also showed that the different microflora differed in their metabolic characteristics which would be expected to affect BOD and COD reduction.

The purpose of this investigation was to investigate the effect of relatively high BOD loading and the presence of various surfactants, at concentrations reported in dairy waste waters on the microflora, performance and some selected characteristics of a laboratory dairy waste treatment system.

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PROCEDURES

The Dairy Activated Sludge Laboratory Model

A single stage, closed continuous extended aerated homogeneous-spatial system was used for this study (Figure 1). The system was adapted to a commercial fermentor assembly (Fermentation Design, Incorporated, Bench Model SA5F1), which possessed controls for agitation, temperature, and air flow rate and pressure. In addition to the fermentor assembly, pH and dissolved oxygen probes and recorders were utilized for continuous monitoring of these parameters during the operation of the system.

Activated sludge was obtained from a dairy waste water treatment operation located in New Bremen, Ohio; immediately frozen in dry ice; freeze dried in a Virtis 10-145 MR Freeze-Dry Mobile unit at a vacuum of 20-50 microns and a temperature of -50 to -70°C until used. A 1.0 g aliquot of the freeze dried sludge was used to inoculate the substrate. Approximately 8 hours were required under the defined growth conditions before growth was initiated.

Commercially pasteurized skimmilk obtained from The Ohio State University Dairy Plant served as the primary source of the model waste water effluent. The skimmilk was diluted with distilled water to yield the desired total solids, heat treated at 121°C for 7 minutes and immediately cooled to room temperature prior to introduction into the treatment system.

The following operating conditions were maintained for all experiments:

Agitation - 160 rpm

Temperature - 23 ± 1°C

Air Flow Rate - 2.0 to 4.0 l/minute

Air Pressure - 6.0 to 11.0 p.s.i.

Substrate and Effluent Flow Rate - 79.8 ml/hour

Dilution Factor - 0.053 (equivalent to 18.8 hours of retention in the system)

Return Sludge - 9 times the substrate flow rate/hour

Fixed Volume in Aeration Tank - 1500 ml.

Material from the sedimentation vessel was collected continuously in a flask, held at 3-4°C. The pooled material was centrifuged at 9000 x G for 20 minutes. The resulting supernatant served as the effluent to be tested, and the sedimented pellet represented the biomass.

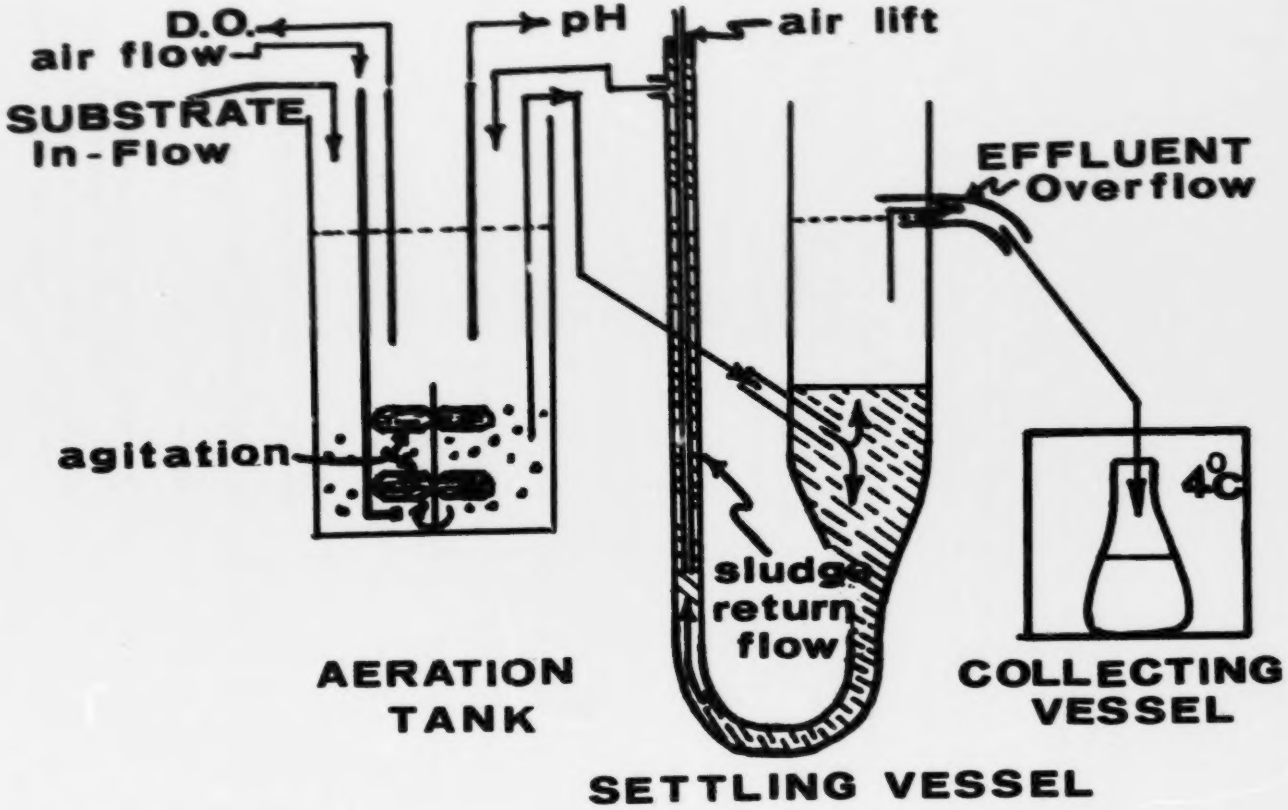

D.O.
air flow
SUBSTRATE In-Flow
agitation
pH
air lift
EFFLUENT Overflow
sludge return flow
4°C
AERATION TANK
SETTLING VESSEL
COLLECTING VESSEL

Figure 1: Schematic diagram of laboratory activated sludge treatment system for dairy wastes

The biomass pellet was washed twice with distilled water, with centrifugation between washings. The washed pellets were stored at -20°C until further use of these cells was required.

A 10 ml aliquot of the reaction vessel mixture (mixed liquor) was obtained from the outlet leading to the settling vessel. This was performed only during the establishment of "steady-state" conditions.

Analytical Procedures

The analysis for Biological Oxygen Demand (BOD), Chemical Oxidation Demand (COD), total, volatile, and fixed suspended solids, and the Sludge Volume Index were carried out according to the procedure outlined in Standard Methods for the Examination of Water and Waste Water, 13th Edition, 1971(20).

Dry weight determinations were carried out according to the procedure outlined in Manual of Microbiological Methods(6).

The Lowry procedure(15) was used for determining protein concentrations of the cellular extract.

Microscopic film slide examinations were made from the outgoing effluent still in the settling vessel prior to collection, settling and centrifugation. A gram stain was performed on the film smear and examined for general shifts in microflora based on morphological characteristics. This was performed routinely throughout the course of the investigation. Pipes(18) Atlas for Activated Sludge Systems was used as a reference.

To disaggregate the cells from adsorbed protein and other material 2.0 g of the biomass was suspended in a 20 ml 0.1 M phosphate buffer at pH 7.4. This suspension was allowed to stand at ambient temperature for 30 minutes.. An addition of 0.4 ml of 2N NaOH adjusted the solution pH to 10.5. The cells were centrifuged out at 4000 x G for 20 minutes. The supernatant was discarded. The cells were resuspended in 10 ml of a 0.1M phosphate buffer pH 7.0. Determination of cell mass weight as a percent of total biomass was determined.

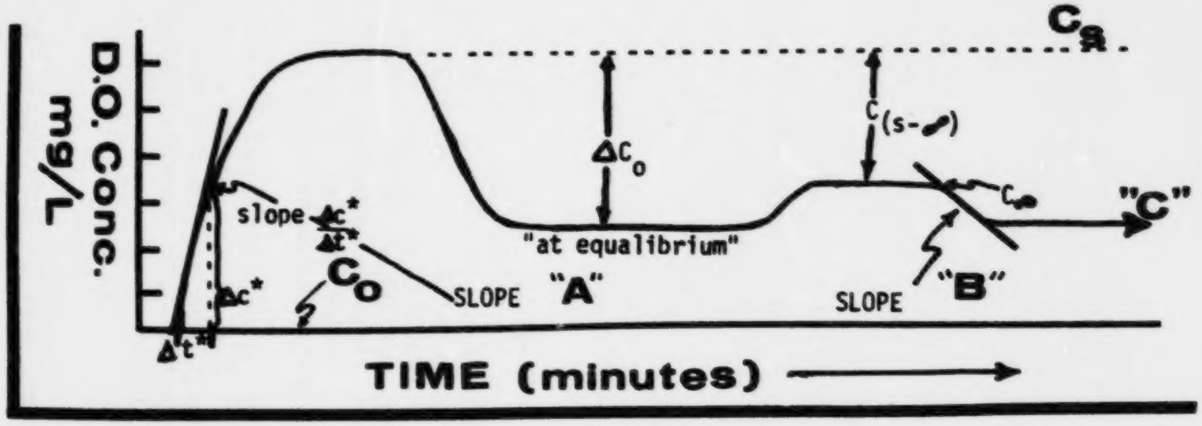
Through consultation, the following mathematical relationships were used to derive experimental K_La oxygen capture and total and endogenous respiration rates. The values for the following equations were obtained from the D.O. record (Figure 2). The mathematical relationships were:

For K_La with cells:

Assumption: Oxygen transfer rate is influenced by "C".

$$K_La = \frac{\text{slope "A"}\ (dc/dt)o}{(\text{"C"} - C_o)} \qquad [1]$$

Figure 2. Dissolved oxygen record used to calculate K_La



WHERE:

C_s = D. O. concentration at saturation for the bulk fluid

C_∞ = "new" D. O. concentration due to change in operational parameters

"C" = established D. O. concentration during operation

C_o = D. O. concentration, initial

Δc^* = change in D. O. concentration

Δt^* = change in time interval, minutes

For K_La without cells:

Assumption: (C_s - "C") is plotted on semi-log paper and slope passes through 1.0 log cycle.

$K_La = 2.3/\Delta t$ Note - Δt is from plotted graph or computed slope. [2]

RESULTS

Effect of BOD Loading

A skimmilk-water mixture as the substrate to yield organic load levels of 1000, 2000, and 3000 mg/l BOD_5 was used to determine the effect of organic load on the characteristics and performance of the treatment system. Each experimental condition under evaluation was allowed to achieve operational equilibrium and "steady-state" prior to initiation of the experiment. Primary indicators of "steady-state" were the substrate flow rate, pH level, dissolved oxygen concentration, and the mixed liquor biomass dry weight. Following achievement of "steady-state" the system was operated for 3-4 days with daily renewal of the BOD loading substrate. All experiments were run sequentially, with no shut down of the fermentation system.

Determinations were made to determine the effect of BOD loading on microflora and selected performance characteristics.

Microflora

The microflora were identified by gram stain and morphological characteristics. No attempt was made to classify the microflora biochemically. Table 1 summarizes the microfloral population shifts at the respective BOD load conditions indicated and are expressed in percentage of the stained morphology of the microorganisms. Shifts occurred in the gram positive rod and gram negative rod populations with changing load levels and these changes were apparent within 24 hours after changing the BOD load. As the BOD load increased from 1000 ppm to 3000 ppm the gram positive rods increased from 11.9% to 48.1% and the gram negative rods decreased from 86.8% to 50.7% of the biomass microfloral population.

Performance Characteristics

Performance data for the sludge system at the three BOD levels are presented in Table 2. As the BOD load level increased, the biomass concentration also increased, with the greatest increase occuring between 2000 and 3000 ppm BOD in the waste water. At the same time the cell mass, as percent of the biomass, did not change consistently with an increase in BOD load, although the percentage of cell mass was higher at both 2000 and 3000 ppm BOD loading than at 1000 ppm BOD loading.

Table 1. Microfloral Population Distribution in the Biomass for Different BOD Loading Levels. (expressed as percentage of total)

Field Distribution	BOD Loading, mg/l		
	1000	2000	3000
Gram Pos. Rods:			
Pleomorphic type	11.9	10.6	48.1
Gram Neg. Rods:			
Single type	72.0	82.9	46.1
Diploid type	14.8	5.6	4.6
Yeast	-0-	0.2	0.5
Filamentous Forms:			
Bacteria	1.3	0.7	0.5
Fungus	0.1	-0-	0.2

Table 2. Effect of BOD loading on performance and selected characteristics of a laboratory activated sludge treatment system for skimmilk.

Determination	Values obtained for following BOD loading levels					
	1000 ppm		2000 ppm		3000 ppm	
	range	average	range	average	range	average
BOD_5Loading/day mg/day	1870 - 2130	1980	3500 - 3900	3690	5504 - 6696	5650
Biomass Concentration (g/l)	2.61 - 2.67	2.64	3.20 - 3.20	3.2	7.9 - 8.4	8.1
BOD removed/g biomass (dry weight)	0.43 - 0.46	0.44	0.58 - 0.62	0.60	0.31 - 0.36	0.33
Cell mass as % of biomass	19.6 - 21.4	20.8	34.6 - 43.2	39.8	21.6 - 30.7	26.5
Retention time(hrs.)	18.2 - 20.0	19.6	19.6 - 22.7	20.7	19.6 - 20.4	19.9
Sludge Age (days)	1.37 - 1.45	1.42	1.03 - 1.17	1.10	1.9 - 2.6	2.3
K_La	0.062 - 0.067	0.065	0.047 - 0.050	0.049	0.046 - 0.046	0.046
BOD removal %	---	98.0/1	---	88.7/1	72 - 74.7	73.7
COD removal %	85 - 91	89.5	77.7 - 83.1	80.7	54.5 - 69.6	62.5%

/1 Estimated values.

The sludge age and "BOD removed per g biomass (dry wt.)" values observed are within the normal operational parameters expected for this type of system. The "BOD removed per g biomass" indicates the daily rate at which the substrate (BOD) is being removed from the waste water. At the 1000 BOD load level, the daily BOD removal rate was observed to be at 0.44 which increased to 0.60 as the BOD load level was increased to 2000 mg/l. In contrast, the 3000 BOD level exhibited a 50% decrease in the BOD removal rate as compared to the 2000 mg/l level. K_La decreased from 0.065 at 1000 mg/l BOD loading to 0.046 at 3000 mg/l loading. The efficiency of BOD reduction decreased from 98% at 1000 ppm BOD to about 73% at 3000 ppm BOD in the raw waste water and COD decreased from 89 to 62%.

The percentage cell mass of the biomass was shown to increase two fold as the BOD load level was increased from 1000 to 2000 mg/l. As the BOD load was further increased to 3000 mg/l, the percentage cell mass of the biomass decreased by 33%.

COD was determined on the substrate and waste water effluent from the model waste treatment system to reflect the total oxidizable organic material present. The COD removal efficiencies were then ascertained from these data to indicate the removal rate of the biodegradable organic material. The COD removal rates under the three different BOD loading levels are presented in Table 3. For the BOD load levels investigated the COD removal efficiencies decreased as the loading concentrations increased. As the BOD loading concentration was increased to 2000 mg/l and 3000 mg/l BOD the average decrease in removal efficiency decreased by 10% and 30%, respectively. The "mg COD removed/g cell, min" data shows the highest removal rate at the 1000 BOD load level with a decreasing COD removal rate observed as the BOD load levels were increased to 2000 and 3000. The "mg COD removed per g biomass" rates did not reflect the same basic trend as the "mg COD removed per g cell, min". The correlation coefficient for the three BOD load levels as compared with the "mg COD removed/g cell mass, min" was a correlation of 0.9989.

Effect of Surfactants

After acclimating the treatment system to a 3000 parts/million BOD loading level, experiments were initiated using various surfactants. These included an anionic detergent, alkylaryl sulfonate (AAS); a nonionic detergent, nonylphenoxypoly (ethyleneoxy) ethanol (NPPE); and a cationic detergent, alkyldimethyl benzyl ammonium chloride (BAC). These were used in concentrations ranging from 13 to 52 mg/l which was within the range reported in dairy food plant waste waters.

In initial experiments the anionic detergent (AAS) was used first at a level of 13 mg/l and subsequently at 52 mg/l. Subsequently, the system was restored in the absence of any

Table 3. Effect of BOD Loading on Rate of COD Removal for a Laboratory Activated Sludge Treatment System for Skimmilk

Loading	Average Values for Following Parameters				
level ppm BOD_5	% COD removed	Cell mass g/1	mg COD removed/1	mg. COD removed/g biomass, min.	mg COD removed/g cell mass, min.
1000	89	0.55	1.96	0.49	2.35
2000	81	1.27	3.09	0.64	1.6
3000	62	2.1	3.9	0.32	1.19

surfactant before going on to the next experiment. The organic load from the skimmilk was maintained at a BOD level of 3000 mg/l.

The percentage population for the control before and after and the two levels of AAS are shown in Table 4. Shifts were observed for the gram positive pleomorphic rods from 48 to 91% as the concentration of AAS was increased to 52 mg/l with a total loss of gram negative rods at the 52 mg/l level of AAS. On removal of the AAS the recovery of the microflora was slow and incomplete. The data in Table 4 for the controlled restored system, at 3000 mg/l BOD, was obtained after two weeks with no AAS in the system. There was a very slight recovery of gram negative rods, a decrease in the gram positive pleomorphic types but a marked subsequent increase in the yeast. At this point an attempt was made to reinoculate the system with the freeze dried sludge used initially. For about three days after addition the performance of the system showed marked improvement but the microflora was unable to sustain itself and returned eventually to the population indicated in Table 4 for the restored control. Performance and COD rate removal data are shown in Table 5 as averages of the three days analyses. The biomass concentration increased from about 8 to 25 grams/liter with the addition of 13 mg/liter of AAS and to about 38 grams/liter in the presence of 52 mg/liter of AAS. Elimination of the AAS did not affect the biomass concentration. The increase in biomass concentration was reflected by a similar increase in sludge age which also remained unchanged upon removal of the AAS from the system. The cell mass percent of the total biomass increased from 26.9 to 33.9 and 46.1% in the presence of 13 and 52 mg/l of AAS respectively. In the restored control this is increased further to 53.3%. The effect of AAS on K_La was similar to that reported in the literature. Thirteen mg/liter of AAS had no effect on the efficiency of BOD or COD removal whereas 52 parts per million reduced the performance efficiency. Removal of AAS from the system allowed full recovery in terms of performance as measured by BOD and COD removal. However, there was a marked effect on the rate of removal COD/gram of cell mass changing from a value of 1.2 to 0.34 in the presence of 13 mg/l and 0.1 in the presence of 52 mg/l. Restoration of the system by removal of the AAS did not restore the efficiency of COD removal per unit of cell mass. Overall the results indicate that the presence of 13 mg/l of AAS, while having little effect on the efficiency had a marked effect on some of the microbiological characteristics of the system and markedly reduced the rate of COD removal per gram of cell mass. The higher concentration of AAS did affect the efficiency and further reduced the rate of removal per unit cell mass. These changes could not be reversed by the removal of the AAS over a two-week period of time.

The next series of experiments were conducted with a nonionic detergent (NPPE) at 13, 26, and 39 mg/l. The effect of this surfactant on the microflora of the system is shown in Table 6.

Table 4. Microfloral Population Distribution in the Biomass for a BOD Loading of 3000 mg/l in the Presence of Alkylaryl Sulfonate (expressed as Percentage of Total)

Field Distribution	Experimental Conditions			
	Control Before	13 mg/l AAS	52 mg/l AAS	Control Restored/1
Gram Pos. Rods:				
Pleomorphic Type	48.1	47.5	91.8	66.4
Gram Neg. Rods:				
Single Type	46.1	31.8	-0-	7.2
Diploid Type	4.6	6.9	-0-	-0-
Yeast	0.5	10.0	4.9	24.4
Filamentous Forms:				
Bacteria	0.5	1.9	3.3	1.0
Fungus	0.2	1.9	-0-	1.0

/1 Data taken 2 weeks after removal of surfactant (AAS) from the skimmilk

Table 5. Effect of Anionic Detergent (AAS) on the Performance and Rate of Biological Oxidation of Skimmilk (3000 mg/l BOD_5)

Parameter	Average values for the following			
	Initial Control	13 mg/l AAS	52 mg/l AAS	Restored Control
Biomass concentration g/l	8.1	25.5	37.6	37.7
Retention time (hrs)	20	20.3	20	19.6
Sludge age	2.3	5.4	10.3	10.5
Cell mass as % of biomass	26.9	33.9	46.1	53.3
K_La	0.046	0.15	0.08	0.06
% BOD removal	73.7	73.1	65.1	74.9
% COD removal	62.5	65.4	49.2	67.7
Cell mass g/l	2.1	12.9	26.2	30.4
mg COD removed/min	3.9	4.6	2.9	4.5
mg COD removed/g biomass, min	.32	.12	.11	.08
mg COD removed/g cell mass, min	1.19	0.34	0.11	0.14

Table 6. Biomass Microfloral Population Distribution, as Percentage, for a BOD Loading of 3000 mg/l in the Presence of Nonylphenoxypoly (ethyleneoxy) Ethanol.

Field Distribution	Experimental Conditions				
	Initial Control	13 mg/l NPPE	26 mg/l NPPE	39 mg/l NPPE	Restored Control
Gram Pos. Rods: Pleomorphic type	66.4	88.7	85.1	81.2	90.1
Gram Neg. Rods: Single type	7.2	5.8	8.7	-0-	-0-
Yeast	24.4	3.9	5.2	18.8	5.0
Filamentous Forms: Bacteria	1.0	1.6	0.7	-0-	4.3
Fungus	1.0	-0-	.3	OUTGROWTH	0.6

The surfactant affected the initial decrease in yeast and an increase in the gram positive pleomorphic rods. At the highest concentration (39 mg/l) all gram negative rods were eliminated and concentration of yeasts increased at the expense of the gram positive rods. Elimination of NPPE from the system was followed by a decrease in the yeasts and an increase in the gram positive rods and in the filamentous forms as fungi.

The effect on performance and rate of COD removal is shown in Table 7. This surfactant had a different effect on the performance and characteristics of the system. The efficiency of BOD and COD removal were partly effected even at 13 mg/l with very little further effect on increasing the surfactant concentration. At the same time the rate of COD removal per unit cell increased with increasing concentrations of surfactant. In contrast the percent of cell mass of the total biomass was markedly decreased by the surfactant, although the total biomass concentration showed relatively little change. Attempts to restore the system were generally unsuccessful with inability to show recovery of BOD and COD removal efficiency or influence in rate of COD removal. This is also in contrast to the K_La which was markedly increased by the surfactant but returned to normal in the absence of the surfactant in the system.

Because of failure to return the performance efficiency system to anything like normal the results with the cationic detergent are extremely difficult to interpret. This surfactant increased the filamentous forms of the microorganisms; increased the K_La from .06 for normal operation to .76, .38 to .66 for 13, 26, 39 mg/l of cationic surfactant (BAC), respectively, though the K_La returned to normal when the BAC was removed. COD removal was essentially unaffected, remaining about 45% for all levels of surfactant but upon removal dropped to 30%. The mg COD removed/gram of cell was .57, .75, and .74 for 13, 26, and 39 mg/l, respectively, with a percentage cell mass of biomass of 9.8, 7.0, and 8.2 for these levels, respectively. After removal of BAC the cell mass percent of biomass was 11% but the milligram of COD removed per gram was 0.28. Further experiments are needed in this area to more fully understand the potential effect of the cationic surfactant.

DISCUSSION

BOD Load Factors

The biological oxidation process involves several factors which influence the removal of organic material from wastewater and effect microbial metabolism.

A laboratory extended aeration activated sludge system was maintained for the purpose of investigating the bio-oxidation process. This system demonstrated an initial BOD removal

Table 7. Effect of a Non-Ionic Surfactant (NPPE) on the Performance and Rate of a Biological Oxidation of Skimmilk (3000 mg/l BOD_5).

Parameter	Average values for the following				
	Initial Control	13 mg/l	26 mg/l	39 mg/l	Restored Control
Biomass concentration in g/l	37.7	34.8	36.6	40.5	29.0
Retention time (hrs.)	19.6	19.9	19.0	19.8	20
Sludge age	10.5	11.8	10.3	10.7	6.6
Cell mass as % of biomass	53.3	39.9	13.8	9.0	12.3
K_La	0.06	0.36	0.39	0.55	0.06
% BOD removal	74.9	59.1	55.5	51.0	50.0
% COD removal	67.7	45.1	45.0	43.9	43.6
Cell mass, g/l	30.4	13.8	5.0	3.7	3.6
mg COD removed/min	4.5	3.3	2.8	2.9	2.4
mg COD removed/g biomass, min	0.08	0.06	0.05	0.05	0.06
mg COD removed/g cell, min.	0.14	0.16	0.38	0.54	0.46

efficiency at 89.5% for the 1000 mg/l BOD loading phase of this study. This BOD removal efficiency is in agreement with reported literature values for this type system. As the BOD loading was increased, the BOD removal efficiency decreased to a low of 65.1% for the 52 mg/l AAS trial.

A performance factor which is closely associated with BOD removal efficiency is that of sludge age. Sludge age is defined as follows:

$$\text{Sludge Age} = \frac{\text{Volume of Aeration tank} \times \text{Biomass dry weight}}{\text{Daily Flow Rate} \times \text{COD removed} - \frac{(dX)}{(dt)}} \qquad [3]$$

During the course of the experimentation, the sludge age increased to approximately 10 days old. The most efficient BOD removal occurred with a sludge age of less than 2 days for this type activated sludge system.

Another performance factor which indicates the activated sludge's BOD removal capacity is the system's retention time. Usually the BOD removal capacity correlates with the retention time and provides a convenient check on the system's performance, assuming all other performance factors are within the normal operational parameters. This correlation ($r = 0.15$ to 0.30) did not exist for this activated sludge system. Two possible reasons for this lack of correlation would be the continually shifting microfloral population distribution and changing cellular growth rates.

Another performance parameter of significance was the daily BOD removal rate per biomass (dry wt.) which is defined as BOD removed, mg/biomass dry weight, g. At the start of this study, the BOD removal rate was 0.45 which increased to 0.60 for the 2000 mg/l BOD loading level, and then declined to an average rate of 0.335 for the 3000 mg/l BOD load.

The most critical factor of any waste treatment system is the microflora distribution of the activated sludge. The type of microflora present effects the removal rate of the wastewater substrate and stabilization of the final effluent.

It was observed that the gram negative bacteria were the predominating microflora throughout the course of the three BOD load levels. However, as the BOD load level was increased from 1000 to 2000 mg/l, a shift downward in the gram negative bacteria and an increase in the gram positive pleomorphic bacteria was noted. This trend continued as the BOD load level was increased to 3000 mg/l. Correlated with these shifts were decreasing BOD and COD removal capabilities of the waste treatment system which could be attributed to the decline of the gram negative bacteria in the activated sludge system. Adamse(1) suggested one possible explanation for the loss of the gram negative rods. He suggested that the inability of the gram negative rods to store polysaccharides places these type bacteria at a disadvantage. Those microorganisms that can store polysaccharides can then use this material for a source of cellular energy when all the exogenous substrate (i.e. lactose) has been removed from the system. The second possible explanation would be catabolite repression stimulated by high concentrations of glucose or galactose (4) derived from the lactose.

Experimental evidence also showed a decrease in the COD removal capability and a shift in the gram positive pleomorphic rod population as the BOD load levels were increased to 2000 and 3000 mg/l levels. These type bacteria appeared to be less effective in the removal of COD. Additionally, increased biomass weights and percentages of biomass cells were observed without improved BOD or COD removal rates. Possibly, the presence of high carbohydrate and protein concentrations have disturbed the substrate transport mechanisms along with a suppression of the mass transfer coefficient.

The Surfactant Factors

The early work of Hoover, Porges, and their associates(12,13,14) on diluted skimmilk laid the foundation of our current understanding of the fundamentals of biological oxidation of dairy food plant wastes. This investigation is aimed to extend the findings of these and other earlier investigators with particular attention to the effect of higher BOD_5 levels and the contribution of selected surfactants found in dairy food plant waste waters on biological oxidation.

The effect of BOD load on activated sludge systems has been given much consideration, but little attention has been given to dairy wastes in excess of 2000 ppm BOD_5. Increasing BOD loading in activated sludge treatment systems has long been recognized to affect sludge characteristics and the performance of the system. However, the effect of high BOD loading on substrate removal rate has been considered to be minimal for dairy food plant wastes. Kornegay and Andrews(14) reported that substrate removal rate approached a constant value as substrate loading level increased.

Before discussing the details of the specific findings in this investigation, attention should be directed to two innovations that appear to have merit in laboratory waste treatment studies: the use of freeze dried dairy activated sludge as a "starter" and the development of a method to separate cells from aggregated debris in the biomass.

The use of freeze dried sludge from a well operating activated sludge system to establish a normal microflora for a dairy activated sludge system worked well, and this concept has potential value in dairy waste treatment. Although the concept to use the freeze dried sludge as a "starter" to re-establish the normal desired mixed flora to an upset system did not work under the conditions of these experiments, limited field work has suggested that the addition of "starters" to commercial activated sludge treatment systems improved performance and its efficiency which makes this approach worthy of further investigation.

For biochemical studies on the cells of the activated sludge system, the results of which are to be reported in a subsequent paper, it was necessary to develop a procedure to separate the microbial cells from the associated colloids and debris in the biomass. The method reported in this paper also provided a means of determining the proportion of the total biomass that was composed of microbial cells. Microscopic examination revealed almost complete separation of cells and noncellular matter. This provided a means for following changes in the microbial cell biomass ratio and to calculate removal of substrate both on a total biomass and on a microbial cell basis. This permits some estimation of the relative role of physical-chemical aggregation of emulsoids and colloids and the microbial cell population.

Increasing the BOD loading had an immediate effect on the performance and characteristics of the waste treatment system. The changes were apparent in the first 24 hours after a change in loading and persisted during the three consecutive days of operation at the same level. The most significant changes were the loss of gram negative microorganisms in the microflora, the increase in biomass (sludge) concentration, the decrease in BOD and COD removal percentages, increase in cell mass, increase in the percent of cells in the biomass and the decrease in the rate of COD removal per unit weight of microbial cells. Of less significance were the change in sludge age, K_La and rate of COD removal per unit of biomass. In terms of overall rate of substrate removal, the values did approach a maxima as suggested by Kornegay and Andrews(14).

Although full interpretation of the findings is difficult, the loss of performance efficiency as a function of increased BOD loading would appear to be related primarily to the reduction of substrate removal efficiency per unit mass of microbial cells which is associated with the change in the microflora. The loss of efficiency of the rate of removal of COD per unit cell mass is a first order reaction in respect to BOD loading level. This loss, in percentage, is greater than the loss of performance efficiency. This apparent discrepancy can be accounted for in the increase in percentage of cells in the biomass at both 2000 and 3000 mg/1 BOD as compared to the control at 1000 mg/1.

The effect of an increase in the BOD load on the characteristics and performance of the activated sludge system was greater between 2000 and 3000 mg/1 BOD, than it was between 1000 and 2000 mg/1. There was a 2-1/2 fold increase in the biomass concentration and a loss of microbial cells in the biomass at 3000 mg/1 as compared to the 2000 mg/1 level. Based on these data, levels of BOD loading above 2000 mg/1 should be avoided in all cases. This can be achieved through better in-plant control and the installation of engineering systems designed to reduce BOD loads(11).

Harper, et al.(11) reported data for surfactant concentrations in dairy food plant waste waters ranging from about 12 to 60 mg/l and expressed concern of the effect of these materials on dairy food plant waste treatment. The data obtained in this investigation confirm this concern and extend the knowledge of the effect of surfactants on an activated sludge system beyond that of pevious investigators(10,16,17). In addition they provide specific information on the role of surfactants on the biological oxidation of dairy wastes at high BOD loading levels. Manganelli(16) studied anionic and nonionic and cationic surfactants at levels between 5 and 100 mg and found that a cationic detergent concentration from 10 to 100 mg tended to suppress sewage oxidation and oxygen utilization. Edwards et al.(10) gave attention to the effect of surfactants on the interaction with proteins and the tendency to increase foaming characteristics. McClelland(17), studying two different anionic surface active agents, showed that the surfactants tended to concentrate in air-water and biomass-water interfaces. The results suggested that the absorbed anionic surfactant interferred with the production and availability of extra cellular hydrolytic enzymes and act as a barrier between the substrate molecule and its respective enzyme site. Most of these workers have attributed the effects of surfactive agents primarily on decreasing the efficiency of aeration and to some effect on the activity of certain biological units.

Our studies on the anionic surfactant had the expected effect on the oxygen diffusion rate. The new information from the results of this investigation were the effects on the microflora, sludge age, percentage cells in the biomass and the rate of COD removal per gram of cell. Although the efficiency as measured by BOD and COD removal were uneffected at the 13 mg/l level of the anionic surfactant, sludge age was doubled, the percent of cells biomass increased and the rate of COD removal per unit of cells was decreased by about 70%. The higher level of anionic surfactant did materially reduce the efficiency of the system and totally eliminated gram negative organisms from the treatment system. This was accompanied by a five-fold increase in sludge age as compared to the control and a 90% reduction in the rate of COD removal per unit of cell mass. The fact that the percentage of cells in the total biomass almost doubled as compared with control provided some off setting influence on the overall apparent performance. A secondary effect of considerable importance was, whereas the overall sludge mass increased about five-fold the cell mass increased ten-fold. This suggests that the anionic surfactant used in the experiments markedly reduced the physical-chemical aggregation of colloidal material to the biomass.

The results obtained upon the removal of the anionic surfactant from the system are not easy to explain. The K_La value returned to nearly normal and the percentage of BOD and COD removal were slightly higher than the initial control. The rate of COD removal per unit cells, however, remained about 1/10 that of control and the cells total biomass increased to 82%. There was only a slight recovery of gram negative organisms in the system.

The non-ionic detergent, while having a marked effect on BOD and COD removal efficiency at 13 mg/l level, had quite a different effect on other characteristics of the treatment system which were also different than those obtained with the anionic detergent. Increasing levels of the surfactant had basically no effect on the BOD and COD removal percentages. In contrast to the anionic surfactant the sludge age was unaffected as compared to the control, and concentration of the biomass was not significantly affected by the surfactant. However, there was a reduction in the cells present in the biomass, with about 1/5 as many cells in the system containing 39 mg/l of non-ionic detergent as compared to control. The rate of COD removal per g cells, however, was actually improved by the presence of the surfactant. These results might be interpreted to indicate a tendency for the surfactant to interact with colloidal and emulsoid material and to further the interaction of these materials to the total biomass. This was in spite of a decrease in sludge age, a marked decrease in the biomass concentration and an improvement of the rate of COD removal per unit cells. However, the system performance did not recover during a two-week period after removal of the surfactant. The reasons are not understood at this time.

Subsequent application of cationic surfactant to the system completed the essential destruction of the system as a viable waste treatment unit. It appeared that the various surfactants had an additive effect and that the microflora was so altered that recovery was not possible.

There is need for continued investigations of the fundamentals of dairy waste treatment systems for the development of methods to either eliminate surfactants or to improve the performance of the systems in the presence of surfactants that would be present in current dairy food plant wastes.

SUMMARY

This investigation showed that high BOD loading (3000 mg/l) was unsatisfactory from the standpoint of the utilization of a laboratory activated sludge system. Increased BOD loading from 1000 to 3000 mg/l altered the microflora very rapidly, reduced the efficiency of BOD, COD removal, and decreased the rate of COD removal per unit weight of microbial cells. Alterations were effected also in respect to K_La, percentage of microbial cells in the sludge and a slight increase in sludge age.

Anionic and non-ionic surfactant concentration found in dairy food plant wastes did influence the characteristic performance of the system but not necessarily in the same manner. The anionic detergent resulted in an increase in cells in the biomass, a decrease in the rate of COD removal per unit microbial cell mass, and a decrease in performance efficiency at high levels of surfactant. The non-ionic surfactant had a deleterious effect on performance at 13 mg/l but increasing concentrations had no further effect on performance efficiency. However, there was a tendency for a BOD increase in the percentage of microbial cells in the biomass as non-ionic surfactant concentration increased and a co-comitant increase in the rate of COD removal per unit of weight of cells.

From these experiments it would appear that anionic detergents are superior to either non-ionic or cationic since removal of the surfactant permits recovery of the performance characteristics of the system and the concentrations required to create and influence are higher with the anionic than with the other surfactants.

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CHARACTERIZATION AND TREATMENT OF FISH PROCESSING PLANT EFFLUENTS IN CANADA

by

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SECTION I

INTRODUCTION

Canada's position as a major fish processing nation can be judged from the 1970 Fisheries Statistics. During that year, approximately 1.5 million metric tons of fish (live weight) were landed in Canada with a landed value in excess of $200 million. Canada exported some 380,000 metric tons of processed fish with a value of $247.4 million. This makes Canada the second largest fish exporting country in the world behind Japan.

Table 1 below summarizes the landings in volume and value for 1970 for both Atlantic and Pacific Regions as well as freshwater fish. It should be noted that the Atlantic region processes 85% of the fish catch by volume, however this only represents 65% of the total landed value and 70% of the total marketed value of all fish landed in Canada.

Table 1. Volume and Value of Seawater and Freshwater Fish Caught in Canada (1970 Annual Statistics Review of Canadian Fisheries)

	Landings ($lbs \times 10^6$)	Landed Value ($\$ \times 10^6$)	Marketed Value ($\$ \times 10^6$)
Atlantic	2375.1	131.6	290.0
Pacific	238.5	60.2	110.0
Sea Fisheries Total	2613.6	191.9	400.0
Freshwater Fisheries	120.0	15.6	22.0
Canada Total	2733.6	207.5	422.0

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Table 2 below summarizes the volumes and landed value of the 10 major fish species landed in Canada. It should be noted from table 2 that the herring catch represents approximately 40% of the total volume landed but the landed value of herring represents approximately 16% of the total landed value of the 10 major fish species. In comparison salmon landings account for approximately 6% of the total volume landed with a landed value of approximately 25%. During the 1971-72 fishing seasons the herring catch declined markedly and as a result the use of herring for fish meal production has been discouraged.

Table 2. Volume and Landed Value of Ten Major Species (1970 Annual Statistics Review of Canadian Fisheries)

No.	Species	Volume Landed (lbs x 10^3)	Landed Value ($ x 10^3)
1	Herring	1,064,400	13,539
2	Cod	494,836	23,180
3	Small Flatfish	311,180	15,486
4	Redfish	243,855	8,056
5	Salmon	159,490	48,030
6	Haddock	49,477	5,296
7	Lobster	36,584	29,661
8	Mackerel	34,613	1,253
9	Halibut	32,981	12,179
10	Turbot	26,097	1,092
Canada - Total of 10 Major Species		2,733,600	207,500

In 1970 the Canadian fishing industry supported a commercial fleet of 39,350 boats with a value of $267 million. The industry employs some 53,000 fishermen of which 41,700 work in the Atlantic provinces of Nova Scotia, New Brunswick, Prince Edward Island, Quebec and Newfoundland.

Table 3, below, summarizes the number of fish processing plants and persons employed in these plants by province for 1969. It should be noted from this table that, although there are some 450 processing plants in Canada, the number of persons employed in these plants is approximately 19,000, giving an average of approximately 30 persons per processing plant. Plant processing capacity ranges in size from 60 million pounds of raw fish processed per year to approximately 100,000 lbs. of raw fish processed a year. The largest plants employ in excess of 300 persons where as the smallest operations are usually run by a single family.

Across Canada the industry provides necessary employment for a large number of small communities. These communities, most of which are scattered along both coastlines are dependent to a significant degree, if not wholly, on the fishing industry for their livelihood. The industry also plays a significant role in the lives of both Indian and Eskimo native peoples both as a source of food and a means of commercial livelihood.

Table 3. Number of Fish Processing Plants and Persons Employed in these Plants by Province
(1969 Dominion Bureau of Statistics, "Fish Products Industry")

Province	Number of Fish Processing Plants	Number of Persons Employed
Nova Scotia	136	5,177
New Brunswick	92	3,219
Prince Edward Island	23	597
Quebec	46	1,414
Newfoundland	71	5,104
Ontario & Prairie Provinces	35	923
British Columbia	57	2,725
Canada - Total	460	19,159

Current methods of processing fish require the use of considerable quantities of water for: cleaning the fish, transporting the waste material, plant clean-up, and use in deodorizers. The discharge of this waste water directly into adjacent lakes and rivers solved the disposal problem of the fish processors for many years. In recent years the expansion and consolidation of the fish processing industry and the improvement of the by-product recovery techniques has made it economical to remove the large solid material from the waste water by screening. The screenings were processed and the resulting fishmeal was sold as animal feed, but the remaining waste waters still have been discharged to receiving waters.

As a result of the discharge of this waste water, and the inefficient operation of offal screening devices, serious pollution problems have occurred around fish processing plants. This has been aggravated by the congregation of a number of plants around harbour areas. These plants then discharge their waste material into the harbour which is not subjected to the tidal flushing action required to sufficiently dilute these waste and thus prevent pollution problems.

The fishing industry relying on a renewable resource is often affected by pollution. However, it is difficult for the Canadian fishing industry to lay the blame at other industrial polluters when it is also contributing to this pollution. It therefore seems reasonable to expect the fishing industry to take an exemplary position with respect to water pollution control. However, one of the major problems has been the lack of information on waste characteristics and type of treatment that could be effectively employed. In order to aid the industry in its fight against water pollution, the Canada Department of the Environment has undertaken a number of studies to characterize and to determine the treatability of the effluents from various processing plants. These studies will be discussed in this paper. Firstly, however, it is necessary to outline the major processing techniques employed in this industry as well as to review the literature to obtain an indication of the present level of knowledge in the characterization and treatment of these wastes.

SECTION II

PROCESS DESCRIPTIONS

The processes which characterize the fish processing industry in Canada can be divided into the following five major groups:

- Groundfish processing
- Herring processing
- Salmon processing
- Shellfish processing
- Fishmeal processing

Each group has a unique production process and consequently unique effluent characteristics. Variations in processing procedures are found from plant to plant, but the major features of each type of production are quite consistent and are discussed below.

2.1 Groundfish Processing:

Cod, halibut, ocean perch (redfish), sole and flounder are the species of fish referred to as groundfish. With the exception of halibut the remaining species are processed in somewhat the same manner.

2.1.1 Cod, Redfish, Sole and Flounder:

The fish are either stored whole in the ship or are eviserated prior to storage, the viscera and blood being washed overboard. At the wharf, unloading is usually accomplished by pitching the fish into a basket that has been lowered into the hold. The fish are then weighed, washed and iced in tote boxes. In some larger plants, mechanized unloading methods are used to minimize manual handling.

Most groundfish require no pretreatment prior to filleting, but the scales must be removed from redfish before they can be filleted. The descaling of redfish is accomplished in a revolving cylindrical screen which removes the scales by the abrasive action of the fish rubbing against themselves.

In small plants, the fish are processed by hand. The fillets are cut on a wooden board next to a sink, washed and immediately iced in boxes for distribution.

Most plants processing fillets use mechanized equipment. First, the fish are washed in large wash tanks or by water sprays in large rotating tumblers. Next the fish pass to filleting machines or hand filleting tables. Filleting machines only operate on certain fish sizes and shapes, but considerably reduce labor costs and increase yields, over hand-filleting. The skin is removed from fillet by hand or machine. The solid wastes from filleting and skinning operations are usually rendered for pet food or animal meal. Figure 1 outlines a typical groundfish filleting operation.

The skinned fillets are transported by conveyor belt through a washing tank and, in some cases, a brining tank. After inspection the fillets are packed into containers by hand or frozen and then packed. Steaks are produced from the eviscerated fish by cuts made at right angles to the backbone. These steaks are marketed frozen or fresh. Fillets are marketed frozen (fresh or breaded), chilled or fresh.

2.1.2 Halibut:

After being landed on the vessel, the halibut are dressed by removing the viscera and cutting away the gills. The halibut are then packed in ice in the hold. Halibut are ordinarily processed in relatively small plants. The fishermen usually behead the fish before sale to the processor.

If the fish are not processed immediately, they are re-iced in the fish plant. The majority of halibut are filleted and marketed frozen, however, some are frozen whole or sold fresh.

Prior to whole freezing, a continuous belt washer sprays the fish. The fish are frozen with a glaze protection at approximately -20°F.

Halibut are cut in fletches (boneless and skinless pieces produced from fresh fish). This process divides the halibut into four or more trimmed meaty protions weighing from 5 to 20 pounds. The fletches are frozen and either glazed or packaged in moisture proof wrapping. Other forms of fresh or frozen halibut include packaged fillets, steaks, and breaded fillets.

2.2 Pelagic and Estuarial:

The most important pelagic and estuarial species are salmon and herring.

2.2.1 Salmon:

The five main species of salmon are spring, sockeye, coho, pink and chum. The major portion of the catch (approximately 80%) is canned.

Spring, coho, and some sockeye salmon are caught using a trolling technique whereas the remaining species of salmon are netted. Troll caught salmon are gutted at sea and subsequently stored in ice. Following unloading a small portion are usually sold fresh while the balance is frozen and glazed for sale in this form or as steaks cut from the frozen fish.

Net caught fish are usually taken close to the canneries and are often held for short periods in the boats without refrigeration. Canning operations are conducted for the most part employing standard cannery equipment in a conventional manner. The principal exception is the use

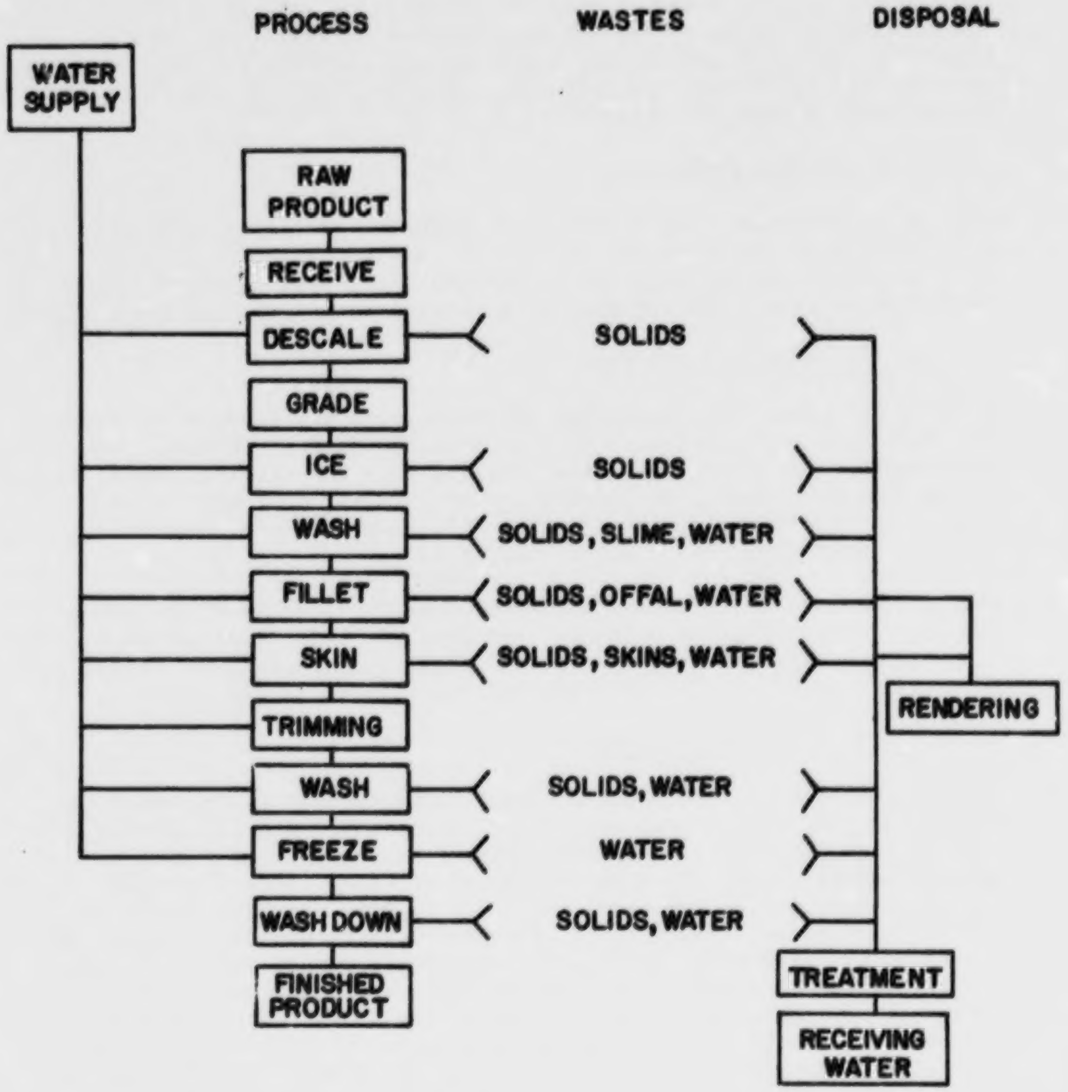
PROCESS
WASTES
DISPOSAL
WATER SUPPLY
RAW PRODUCT
RECEIVE
DESCALE
SOLIDS
GRADE
ICE
SOLIDS
WASH
SOLIDS, SLIME, WATER
FILLET
SOLIDS, OFFAL, WATER
SKIN
SOLIDS, SKINS, WATER
RENDERING
TRIMMING
WASH
SOLIDS, WATER
FREEZE
WATER
WASH DOWN
SOLIDS, WATER
FINISHED PRODUCT
TREATMENT
RECEIVING WATER

FIGURE 1. GROUNDFISH FILLETING

of the "iron chink". The iron chink performs several functions in one operation by mechanically removing heads, fins, and viscera. During all the steps a strong stream of water continuously washes the blood away. The remaining canning operations are somewhat standard, as shown in figure 2. The fish are washed, inspected and cut into can-length portions and the cans are filled mechanically. Finally, the cans are automatically sealed under vacuum and then retorted.

2.2.2 Herring Processing:

Herring is processed into a number of products, including fish oil, fish meal, herring fillets, marinated herring, and for the herring roe. This section describes only the operations which process herring for human consumption - herring filleting, marinated herring and herring roe.

2.2.2.1 Herring Filleting:

As with the groundfish processing plants herring are trucked to the plant and stored in holding bins, there being packed in ice. Herring are delivered to the plant round (head, tails, fins and viscera intact) and, in the filleting operation, have the heads, tails, fins and viscera removed by automatic machines. After filleting they are prepared for consumer marketing.

Wastes from herring filleting originate from the fluming of the round herring to the splitting machines, and from the water used in the machines themselves. Offal is removed prior to final discharge of the waste water for further processing in the fish meal operation.

2.2.2.2 Marinated Herring:

In the production of marinated herring, round herring is trucked to the processing plant and stored in iced or refrigerated bins. From the storage bins the herring are either flumed or conveyed to a hand or machine splitting operation where removal of head, tails, fins and viscera takes place. The resulting split fillets are then stored in barrels or vats in a solution of brine and acetic acid for a period of 5 to 9 days. After this period the solution is dumped and the fillets are introduced to a second solution of brine and acetic acid and stored at low temperature for a period of two weeks. While in this stored solution the fillets are called bismarcks. Following this two-week storage period the bismarcks are dumped, skinned, and repacked in barrels ready for distribution. The process is illustrated in Figure 3.

Wastes are produced during the splitting operation, clean-up, and acetic acid brine dumps. The offal is transported to fish meal plants for further processing.

With both the herring filleting and marinated herring processing, the waste is extremely colored, due mainly to the loss of blood during the splitting operation. The coloration does not dissipate readily upon discharge to the receiving waters.

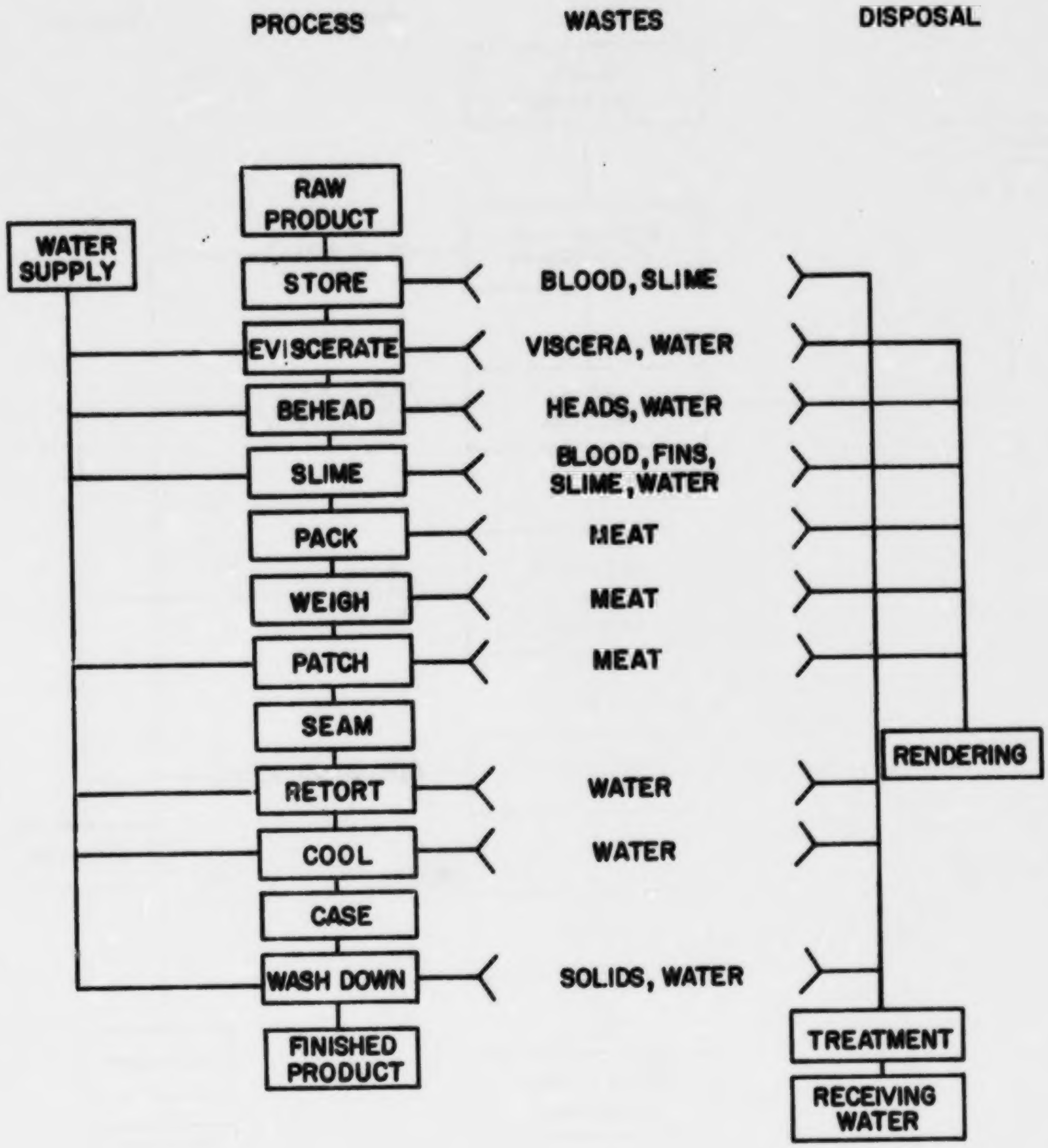
PROCESS
WASTES
DISPOSAL
RAW PRODUCT
WATER SUPPLY
STORE
BLOOD, SLIME
EVISCERATE
VISCERA, WATER
BEHEAD
HEADS, WATER
SLIME
BLOOD, FINS, SLIME, WATER
PACK
MEAT
WEIGH
MEAT
PATCH
MEAT
SEAM
RENDERING
RETORT
WATER
COOL
WATER
CASE
WASH DOWN
SOLIDS, WATER
FINISHED PRODUCT
TREATMENT
RECEIVING WATER

Figure 2. Salmon Canning

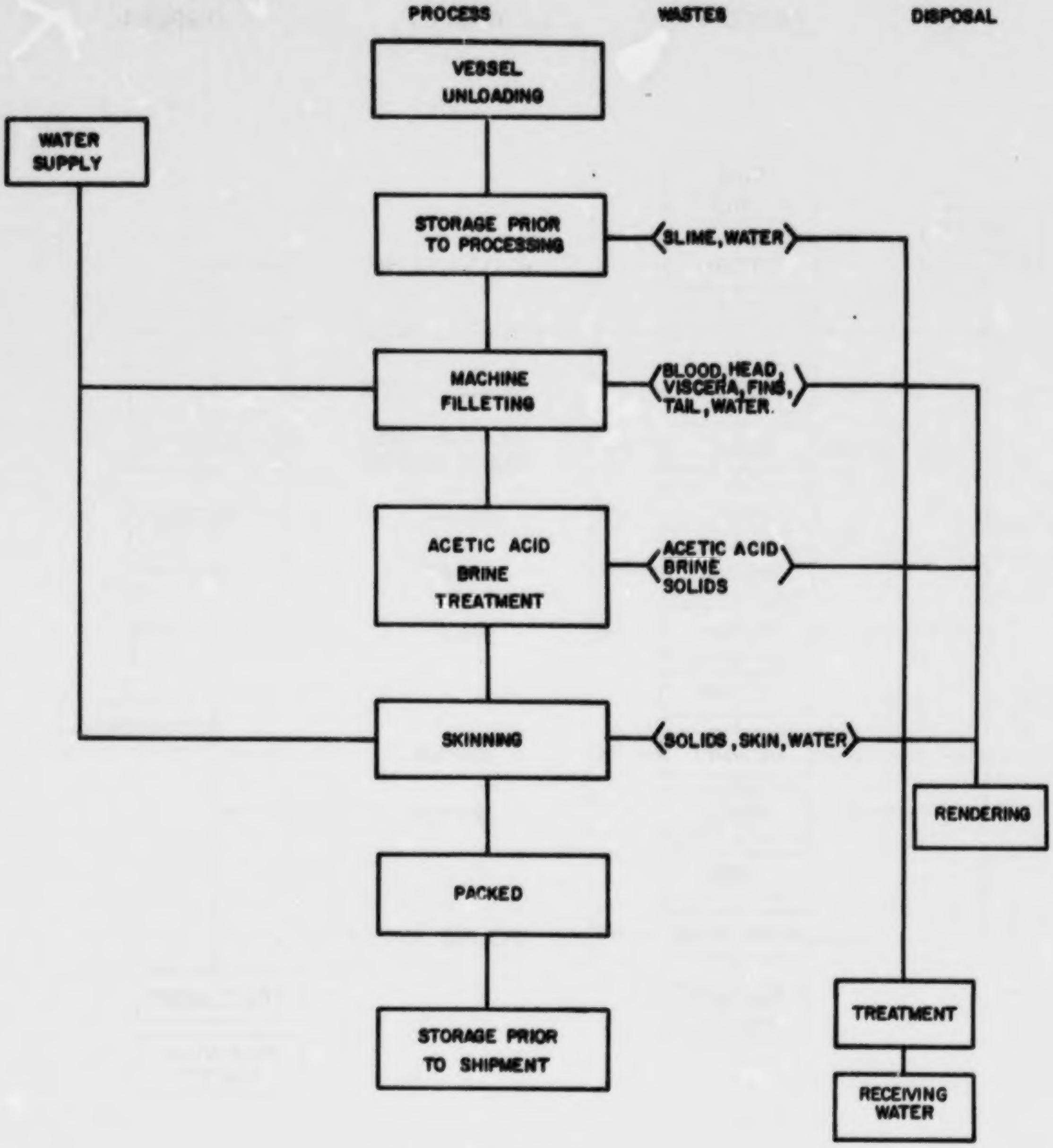
PROCESS
WASTES
DISPOSAL
VESSEL UNLOADING
WATER SUPPLY
STORAGE PRIOR TO PROCESSING
SLIME, WATER
MACHINE FILLETING
BLOOD, HEAD, VISCERA, FINS, TAIL, WATER.
ACETIC ACID BRINE TREATMENT
ACETIC ACID BRINE SOLIDS
SKINNING
SOLIDS, SKIN, WATER
RENDERING
PACKED
STORAGE PRIOR TO SHIPMENT
TREATMENT
RECEIVING WATER

Figure 3. Process Flow Diagram
Marinated Herring Plant

2.2.2.3 Herring Roe:

There has recently been a marked increase in the herring roe industry. The herring are brined prior to process for removal of the roe. The roe are salted, packaged and refrigerated prior to shipment. Following roe removal the remaining herring flesh is sent for reduction to fish meal or to pet food production.

2.3 Shellfish Processing:

Lobster is the major species of shellfish caught and processed in Canada. Lobster are caught in large traps and must be kept alive until processed. Approximately 65 percent of the lobsters are marketed in their shells either alive or cooked. The remaining 35 percent are cooked and shucked.

Lobsters are steam cooked in retorts for 20 to 30 minutes and are water cooled after cooking to facilitate handling. If the lobsters are to be butchered their backs are removed and the remaining viscera are washed free. The cooking, cooling and washing waters contain considerable quantities of solids and organic pollutants.

Small numbers of cooked lobsters and meat are frozen for later marketing. Low storage temperatures and quick turnovers are necessary for the maintenance of high quality. Little lobster meat is canned because of the rapid degradation of texture and flavour quality of the canned product.

2.4 Fish Meal Production:

In the processing of most species of fish for food purposes from 30 to 80 percent of the raw material is waste. Efforts are made by most plants to recover all edible portions, and the recent introduction of deboning machines promises greater utilization in the future. Still, much of the fish poses a disposal problem and one practice has been to produce a protein concentrate for poultry feed. Oil may also be recovered from oily species.

The waste material, termed offal, is normally conveyed wet or dry to the fish meal plant and stored in pits until enough is accumulated to warrant operation. Solids recovered by screening of off-loading and processing water are also sent to the fish meal plant. During storage some liquid is drained or pressed from the offal. This stream called bloodwater, is not large in volume but is very strong in terms of organic content. Some plants attempt to recover this, but most discharge the stream with the plant effluent.

The general flow for fish meal production is shown in Figure 4. The offal is hashed by machine if large pieces are present, and then cooked in direct or indirect continuous steam cookers for up to 10 minutes. Non-oily offal may be added directly to driers, while oily species are pressed to expel most of the water and oil prior to entering the drier.

In the latter case the press liquor undergoes a fine solids separation using vibrating screens or decanting centrifuge followed by oil separation in nozzle centrifuges. The oil is further clarified in polishing

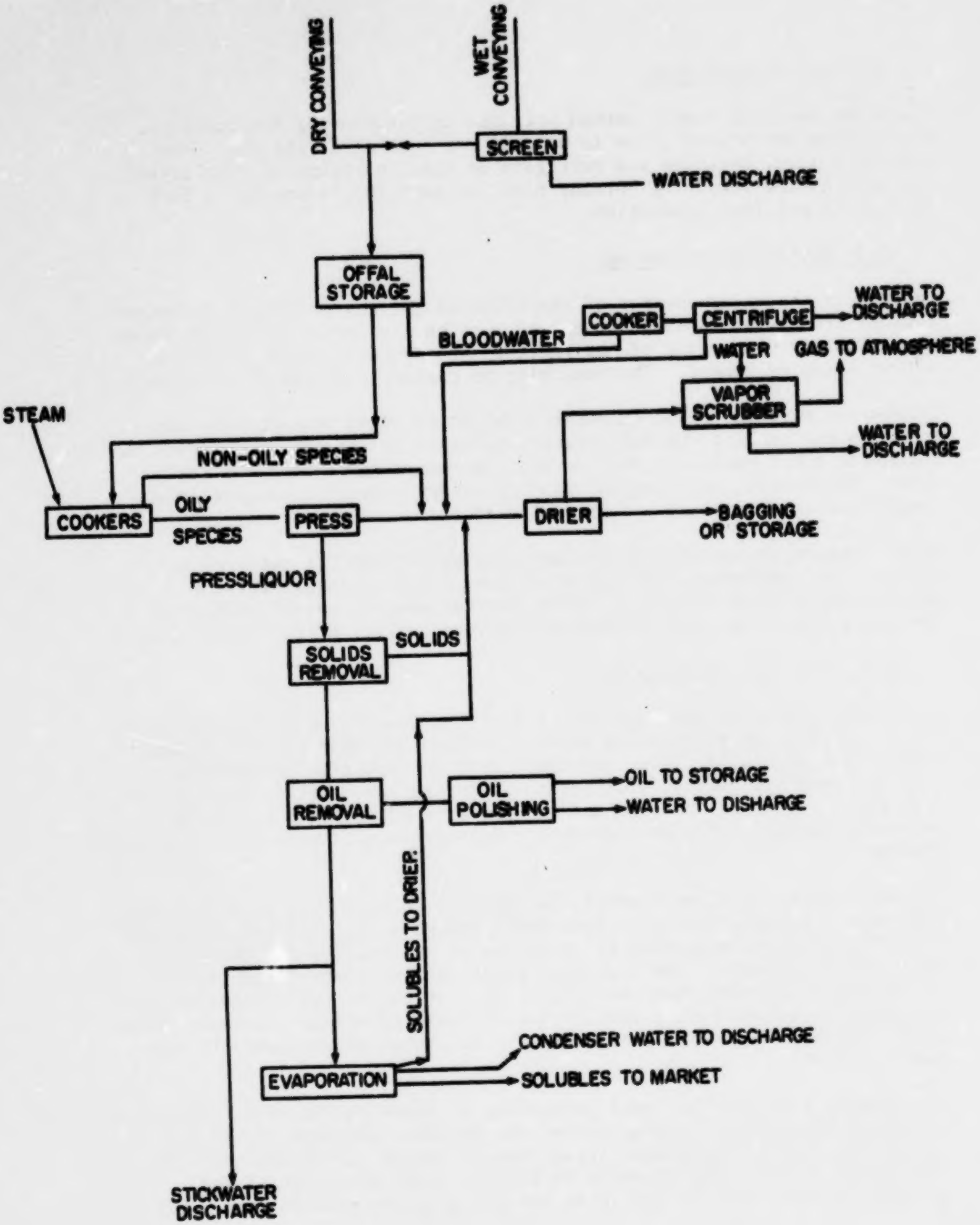
DRY CONVEYING
WET CONVEYING
SCREEN
WATER DISCHARGE
OFFAL STORAGE
COOKER
CENTRIFUGE
WATER TO DISCHARGE
BLOODWATER
WATER
GAS TO ATMOSPHERE
VAPOR SCRUBBER
WATER TO DISCHARGE
STEAM
NON-OILY SPECIES
COOKERS
OILY SPECIES
PRESS
DRIER
BAGGING OR STORAGE
PRESSLIQUOR
SOLIDS REMOVAL
SOLIDS
OIL REMOVAL
OIL POLISHING
OIL TO STORAGE
WATER TO DISHARGE
SOLUBLES TO DRIER
EVAPORATION
CONDENSER WATER TO DISCHARGE
SOLUBLES TO MARKET
STICKWATER DISCHARGE

Figure 4. Flow Diagram for Fish Meal Production

centrifuges before sale as either an edible oil or animal oil. The aqueous phase may still contain up to five or six percent organic solids and is termed stickwater. At one time this was discarded, but now many plants employ multiple effect evaporators to concentrate these solids. The resultant product is termed condensed fish solubles and contains from 30 to 50 percent solids. It is marketed as a poultry or animal feed, a specialty fertilizer, or is recycled back to the driers for incorporation in the meal. The condenser water used in the evaporators does pick up volatile solids and gases, the extent depending on the degree of freshness of the offal and the manner of operation of the evaporators.

The fish meal driers are usually rotary kilns, with heat being supplied by direct flame heating of the air, or by indirect heating using steam. The solids are dried to between 5 to 10 percent moisture content, ground to pass 10 mesh screens and sold in either 100 lb. bags or in bulk. The steam and odors generated during the drying of the meal can be very obnoxious and most plants employ some sort of direct water scrubbing to these vapours prior to release. Large volumes of water are employed for this, and the scrubber effluents will contain a significant quantity of organic material.

Many fish processing plants in Canada combine a number of the above-mentioned operations. For instance, many plants on the West Coast have the capability of processing both groundfish and salmon. These operations might also be linked to a fish meal plant. The resulting wastes from the fish processing plant are usually flumed together and discharged as one effluent, after removal of the offal.

SECTION III

LITERATURE REVIEW

3.1 Characterization Studies:

Fish processing wastes vary considerably in pollutional strength. This variation is due in part to:

1. Species of fish being processed
2. The age of fish being processed
3. The processing techniques
4. Plant size
5. Water usage

The characterization of wastes from various types of fish plants has been the subject of a number of studies. Table 4 summarizes the characteristics of effluents from fish processing plants as reported in 8 different studies and reports. It should be noted that the BOD_5 values are all in the same order of magnitude, however, greater fluctuations occur in the suspended and total solids values. These fluctuations are due to those factors listed above.

Table 4. Characteristics of Effluents from Fish Processing Plants as Reported in the Literature

Author (Fish Processed)	BOD_5 (mg/1)	Suspended Solids (mg/1)	Total Solids (mg/1)
Washington State Pollution Control Commission (1969) (Species of fish not specified)	2700-3400	2200-3020	2198-21,820
Limprich (1966) (Herring, Red Perch, Fish Meal)	2658	--	--
Soderquist *et al* (1970) (Bottom fish processing)	192-1726	300	--
Matusky *et al* (1956) (Wastewater)	1000	425	--
Chun *et al* (1968) (Tuna fish processing)	895	1091	17,900
Soderquist *et al* (1970)			
Salmon processing	397-3082	40-1824	88-3422
Sardine packing	100-2200	100-2100	--
Stanley Associates (1972)			
Halibut	64-150	66-110	--
Sole	160-195	34-85	--
Salmon	390-1900	665-760	--
Shaffner (1970)			
Ocean Perch	390-540	330-1395	--

Table 5 summarizes the characteristics of effluents from fish meal plants as reported in the literature. The major effluents of concern are bloodwater and stickwater, which although very high in BOD_5 and suspended solids are relatively small in volume. This compares to deodorizer water which has a low value of BOD_5 and suspended solids but large volumes of this effluent are produced in fish meal production. The total effluent characteristics as shown in table 5 indicate the result of diluting the high strength low volume wastes, such as bloodwater and stickwater, with the low strength high volume wastes, such as deodorizer water. The results given in table 5 for the different effluents are all of the same order of magnitude. Variations in the results for the total effluents are due to differences in the relative volumes of each type of waste discharged by the fish meal plant. For instance, some plants recover all stickwater while other plants discharge it with their plant effluents.

3.2 Treatability Studies:

The difficulties in the treatment of wastes from fish processing plants are attributable to high flows, medium to high BOD_5 and suspended solids and high grease and protein levels. The short and variable processing season, high peak loadings and rapid biodegradability of the wastes also cause treatment problems.

3.2.1 Physical Treatment:

With the possible exception of the work by F.G. Claggett of the Fisheries Research Board of Canada, which will be discussed later, little work on the physical or biological treatability of fish processing wastes has been undertaken.

A study by the New Brunswick Water Authority (1970) indicated the effectiveness of screening wastes from groundfish processing plants. Using both 10 and 40 mesh screens BOD_5 removals up to 60 percent were reported, however, the median removal value was 33 percent for both screens. Further, the 40 mesh screen provided approximately 25 percent removal of BOD_5 for deodorizer water and for the total effluent from fish meal plants.

Shaffner (1970) concluded that passing the wastewater from groundfish plants over 20 mesh screens would remove approximately 20 percent of the BOD_5 and 16 percent of the suspended solids.

Flotation has been examined as another method of suspended solids removal from fish processing plant effluents. Davis and McKinney (1970) used chemical flocculation and flotation to remove oil and solids from herring pumpwater. It was reported that the organic matter was concentrated from 0.4 percent to a 1.0 percent sludge by pressurized air flotation of a recycled portion of the clarified effluent. Davis and McKinney concluded that, while flotation could recover at least half of the solids remaining in screened pumpwater, it was uneconomic because of its complex operation and the creation of a sludge handling problem.

Table 5. Characteristics of Effluents from Fish Meal Plants as Reported in the Literature

	BOD_5 (mg/l)	Suspended Solids (mg/l)
Matusky et al (1956)		
Stickwater	110,000	125,000
Deodorizer water	800	2,000
Canadian Plant and Process Eng. (1970)		
Stickwater	25,000-72,000	6,500-47,000
Bloodwater	35,000-90,000	40,000-55,000
Total Effluent	18,000-42,500	8,638-23,910
Shaffner (1970)		
Stickwater	34,000	13,270-53,880
Deodorizer water	490	390
Total Effluent	4,400	4,300
Delaney (1971)		
Deodorizer water	47	
Total Effluent	3,180	1,020
Shawinigan Eng. Co. Ltd, (1968)		
Stickwater	38,000	68,010
Total Effluent	257	33,500
Stanley Associates (1972)		
Stickwater	69,000-83,000	10,000-15,000

3.2.2 Biological Treatment:

Soderquist et al (1970) reported that the carbon:nitrogen ratio of fish processing wastewater indicated that biological treatment should be successful. The biochemical oxidation rate was found to be similar to sewage, however, nitrification began sooner and was more significant. Soderquist et al (1970) further reported that a number of authors had found that oil and grease interfered with the oxygen transfer in an activated sludge system. In Soderquist's opinion pretreatment to remove high solids, grease and oil content is a necessity if biological treatment is to be successful.

Matusky et al (1965) stated that fish solids and oil digested readily and the resultant sludge dewatered easily. The digester loading rates varied from 0.1 to 0.36 pounds volatile solids per cubic foot per day.

A review of the literature indicates the current knowledge and process technology involved in the characterization and treatment of wastes from various types of fish plants. It is obvious that if the Canadian fish processing industry is to adequately respond to the need for pollution control better effluent characterization and treatability data must be made available to this industry. Thus the Department of Environment has embarked on a number of projects to collect this data.

SECTION IV

ENVIRONMENT CANADA STUDIES

The studies undertaken by Environment Canada are as shown in table 6. The majority of these studies were carried out during the summer of 1971 or 1972. The exception is study #5, the characterization and treatability of the wastes from a groundfish and salmon processing plant, this study is still continuing and should be complete by mid-1974. The results from these studies will be presented in two parts, the first part being the characterization results and the second part the results of the treatability studies.

4.1 Characterization Studies:

4.1.1 Groundfish:

The groundfish operations involve the processing of halibut, cod, redfish, sole and flounder. Two basic types of processing are used:

a) dry line operations which use a system of conveyors to move the raw product and mechanically operated filleting tables. In the majority of cases offal is removed from the filleting area by fluming.

b) wet line operations characterized by the use of water to flume the raw product and the offal.

In general dry line operations are used in the larger operations whereas the smaller plants rely on wet transport of raw product and offal. In the majority of cases fish are washed in tanks or spray conveyors immediately prior to processing.

Table 6. Summary of Studies of Fish Processing Effluents Undertaken by Environment Canada

Location of Study	Type of Effluent Study	Types of Fish Processed	Processing Techniques	Date of Study
1. Wheatley, Ontario	Treatability and Characterization	Perch & Smelt (Freshwater fish) Fish Meal Production	Filleting	Summer, 1971
2. Lower mainland of British Columbia	Characterization	Groundfish & Herring	Filleting	Summer, 1971
3. Northeast New Brunswick	Characterization	Herring	Marinated and Filleting	Summer, 1971
		Groundfish	Filleting	
		Shellfish, Shrimp Fish Meal production		
4. Maritime Region	Characterization	Groundfish Fish Meal production	Filleting	Summer, 1972
5. Lower mainland of British Columbia	Characteriation and Treatability	Groundfish	Filleting	Continuing
		All species of Salmon	Canning	

4.1.1.1 Dry Line Processing:

Tables 7 to 10 give the BOD_5, suspended solids and ether soluble oil loadings in the effluent from the processing of halibut, grey cod, ling cod, sole and redfish. The results are given in both concentrations, means and ranges, and in pounds of parameter per 1000 pounds of raw product, again in both means and ranges.

Examination of tables 7 to 10 indicates the wide variability in effluent BOD_5 and suspended solids loadings. This variability in loadings not only existed in effluents from the processing of different species in one plant but also in the effluents from processing of the same species in plants of differing size. Table 11 below summarizes the BOD_5 effluent loadings for the processing of sole, grey cod and ling cod - the species processed in the three different sized plants studied (study #2).

Table 11. Summary of BOD_5 Loadings from Groundfish Processing Plants Study #2

Plant Size	Sole	Grey Cod	Ling Cod
Lbs of Raw Product/Day	Lbs BOD_5/1000 Lbs Raw Fish		
6,000	1.4	8.1	6.3
10,000	2.7	2.2	4.1
15,000	0.7	0.9	6.0
Average	1.6	3.7	5.5

Table 12 summarizes the total effluent values for the dry line processing of groundfish. The results indicate the range of BOD_5 loadings for this type of groundfish processing varied from 1.3 pounds of BOD_5 to 7.9 pounds of BOD_5 per 1000 pounds of raw product.

Further examination of table 12 indicates the variability of suspended solids loading of 0.98 to 2.4 pounds per 1000 pounds of raw product and of 0.13 to 1.0 pounds per 1000 pounds of raw product for ether soluble oil (study #2 and #3).

The variability of the effluent in terms of BOD_5, suspended solids and ether soluble oil loadings is considerable due to differences in water usage, age of fish processed, amount of fish processed as well as the processing techniques. A review of tables 7 to 12 indicates that there is no relationship between effluent loadings and plant size.

4.1.1.2 Wet Line Processing:

Table 13 summarizes the total effluent loadings for the wet line processing of groundfish from studies #3 and #4. The BOD_5 effluent loadings

Table 7. Effluent From Dry Line Processing of Halibut and Redfish - Study #2

Plant Size (Lbs raw fish/day)	BOD_5		S.S.		Ether Soluble Oil	
	Conc. (mg/l)	Lbs/1000 lbs raw fish	Conc. (mg/l)	Lbs/1000 lbs raw fish	Conc. (mg/l)	Lbs/1000 lbs. raw fish
	Range ($\bar{x}$)	Range ($\bar{x}$)	Range ($\bar{x}$)	Range ($\bar{x}$)	Range ($\bar{x}$)	Range ($\bar{x}$)
Species: Halibut						
10,000	145-420 (282)	1.3-4.0 (2.6)	95-245 (170)	0.8-2.4 (1.6)	--	--
15,000	-- (204)	-- (4.0)	-- (352)	-- (7.2)	--	--
Species: Redfish						
15,000	40-114 (77)	0.4-1.1 (0.7)	14.4-101.3 (48.9)	0.1-3.5 (1.3)	12.9-35.0 (23.9)	0.12-0.35 (0.2)

($\bar{x}$)=mean

Table 8. Effluent from Dry Line Processing of Grey Cod - Study #2

Plant Size (Lbs raw fish/day)	BOD_5		S.S.		Ether Soluble Oil	
	Conc. (mg/1)	Lbs/1000 lbs raw fish	Conc. (mg/1)	Lbs/1000 lbs raw fish	Conc. (mg/1)	Lbs/1000 lbs raw fish
	Range $(\bar{x})$	Range $(\bar{x})$	Range $(\bar{x})$	Range $(\bar{x})$	Range $(\bar{x})$	Range $(\bar{x})$
Species: Grey Cod						
6,000	120-1775 (607)	0.7-39.1 (8.1)	196-694 (259)	0.6-6.0 (2.5)	9.0-227.7 (61.6)	0.04-5.0 (1.7)
10,000	53-1547 (435)	0.3-7.5 (2.2)	75-1006 (293)	0.4-4.8 (1.5)	0.4-55.2 (16.7)	0.01-0.64 (0.2)
15,000	27-117 (74)	0.4-1.5 (0.9)	20.5-90.0 (44.1)	0.3-0.6 (0.5)		

$(\bar{x})$=mean

Table 9. Effluent from Dry Line Processing of Ling Cod - Study #2

Plant Size (Lbs raw fish/day)	BOD_5		S.S.		Ether Soluble Oil	
	Conc. (mg/1)	Lbs/1000 lbs raw fish	Conc. (mg/1)	Lbs/1000 lbs raw fish	Conc. (mg/1)	Lbs/1000 lbs raw fish
Species: Ling Cod	Range ($\bar{x}$)	Range ($\bar{x}$)	Range ($\bar{x}$)	Range ($\bar{x}$)	Range (x)	Range (x)
6,000	471-1050 (500.1)	2.2-12.7 (6.3)	173.6-517 (248.3)	1.6-5.1 (3.5)	-- (45.7)	-- (0.3)
10,000	30-1102 (468)	0.22-7.4 (4.1)	28-564 (237)	0.21-5.5 (2.2)	-- (320)	-- (0.37)
15,000	54-546 (300)	1.1-11.0 (6.0)	41.6-121.1 (95.5)	0.8-2.3 (1.8)		

($\bar{x}$)=mean

Table 10. Effluent from Dry Line Processing of Sole - Study #2

Plant Size (Lbs raw fish/day)	BOD$_5$		S.S.		Ether Soluble Oil	
	Conc. (mg/l)	Lbs/1000 lbs raw fish	Conc. (mg/l)	Lbs/1000 lbs raw fish	Conc. (mg/l)	Lbs/1000 lbs raw fish
Species: Sole	Range $(\bar{x})$	Range $(\bar{x})$	Range $(\bar{x})$	Range $(\bar{x})$	Range $(\bar{x})$	Range $(\bar{x})$
6,000	96-540 (213.8)	0.3-4.8 (1.4)	92.1-269.8 (124.8)	0.2-1.9 (0.8)	37.6-290.6 (109.4)	0.2-2.3 (1.3)
10,000	200-990 (515)	1.5-7.6 (2.7)	118-908 (332)	0.69-3.2 (1.4)	3.0-526.4 (215)	0.01-4.1 (1.6)
15,000	45-130 (81.8)	0.4-1.1 (0.7)	32.6-173.8 (70.5)	0.04-1.5 (0.6)	0.3-43.6 (10.9)	0.02-0.4 (0.1)

$(\bar{x})$=mean

Table 12. **Total Effluent from Dry Line Groundfish Processing**

Study Number	Plant Size (Lbs raw fish/day)	BOD$_5$		S.S.		Ether Soluble Oil	
		Conc. (mg/l) Range $(\bar{x})$	Lbs/1000 lbs raw fish Range $(\bar{x})$	Conc. (mg/l) Range $(\bar{x})$	Lbs/1000 lbs raw fish Range $(\bar{x})$	Conc. (mg/l) Range $(\bar{x})$	Lbs/1000 lbs raw fish Range $(\bar{x})$
2	6,000	96-1775 (451.5)	0.3-39.1 (5.7)	92.1-1006.4 (226.5)	0.2-6.2 (2.4)	2.4-260.6 (56.8)	0.03-5.0 (1.0)
	10,000	30-1547 (411.0)	0.22-7.6 (2.7)	6.8-1006 (254)	0.1-5.5 (1.6)	0.4-526.4 (93.3)	0.01-4.1 (0.75)
	15,000	27-546 (101.9)	0.4-11.0 (1.3)	14.4-173.8 (64.5)	0.04-3.5 (0.98)	0.33-43.6 (14.6)	0.02-0.4 (0.13)
3	Unknown Plant Size	100-1140 (455)	-- (5.0)	30-232 (135)	-- (1.0)	0-500 (100)	-- (1.0)
4	300,000	178-389 (279)	3.80-15.57 (7.9)	140-576 (290)	2.42-23.06 (22.5)		

$(\bar{x})$=mean

Table 13. Total Effluent from Wet Line Groundfish Processing

Study Number	Plant Size (Lbs raw fish/day)	BOD_5		S.S.		Ether Soluble Oil	
		Conc. (mg/l)	Lbs/1000 lbs raw fish	Conc. (mg/l)	Lbs/1000 lbs raw fish	Conc. (mg/l)	Lbs/1000 lbs raw fish
		Range $(\bar{x})$	Range $(\bar{x})$	Range $(\bar{x})$	Range $(\bar{x})$	Range $(\bar{x})$	Range $(\bar{x})$
3	Unknown Plant Size	602-1205 (1136)	-- (15.0)	148-965 (489)	-- (7.0)	200-1500 (900)	-- (13)
4	250,000	146-648 (295)	-- (18.0)	220-1300 (513)	-- (34.0)		
	180,000	270-750 (520)	-- (20.2)	30-470 (160)	-- (7.1)		
	120,000	300-1005 (584)	-- (18.8)	160-1550 (424)	-- (12.0)		

$(\bar{x})$=mean

vary from 15.0 to 20.2 pounds per 1000 pounds of raw product whereas the suspended solids loadings vary from a low of 7.0 pounds to a high of 34.0 pounds per 1000 pounds of raw product. As with dry line processing these effluent loadings vary widely.

Comparison between the effluent loadings from dry and wet line processing of groundfish (tables 12 and 13) indicates that wet line processing produces an effluent in excess of three times the dry line effluent loadings. These increased loadings are due to:

a) increased BOD_5, suspended solids and oil concentrations in the wet line effluents.

b) water consumption figures (table 14) indicate that wet line processing requires 2 to 3 times the water required for dry line processing.

This variation in the effluent loadings from dry and wet line groundfish processing supports the theory that the longer water is in contact with fish solids the higher the BOD_5, suspended solids and oil concentrations in the effluent. In wet line processing, water is in contact with the fish for considerably longer periods than in dry line processing. Study #1, carried out on freshwater fish processing, also supports this theory.

A major step toward reducing the pollution from groundfish processing plants would be the widescale adoption of dry transporting techniques as opposed to the presently more commonly used fluming methods characteristic of wet line processing.

4.1.2 Pelagic and Estuarial:

4.1.2.1. Salmon:

Spring, coho and some chum and pink salmon are usually glazed and sold whole, while the majority of the remaining salmon catch is canned. The wastes from the canning operation include butchering water, viscera, wash water, retort water and cooling water.

Table 15 shows the values of total effluent from salmon canning and glazing operations as determined from study #2. The results indicate that BOD_5 loadings of about 25 pounds per 1000 pounds of raw fish can be expected form salmon canning using either iron chink or hand processing techniques. The suspended solids in the effluent will vary from about 15 to 25 pounds per 1000 lbs of raw fish.

Water use figures from study #2 indicate that salmon canning requires between 0.9 to 8 gallons per pound of salmon canned. The processing of spring salmon (glazing and storage) requires approximately 1.5 gallons per pound of product.

Frequently, water used in the unloading of salmon at the plant dock is discharged direct to the harbour. Following unloading, the ships holds are washed, this wash water also enters the harbour directly. Table 15 gives the effluent load associated with the hydraulic pumping

Table 14. Water Consumption in Groundfish Processing

Study Number	Plant Size	Process	Water Consumption (fresh and salt) Gals./1000 lbs fish filleted
Study #2	6,000 lbs raw fish/day	Groundfish - dry line	2040
	10,000 lbs raw fish/day	Groundfish - dry line	1630
	15,000 lbs raw fish/day	Groundfish - dry line	3780
Study #3	Unknown Plant Size	Groundfish - dry line	1500
		Groundfish - wet line	4600
Study #4	300,000 lbs raw fish/day	Groundfish - dry line	16,700
	270,000 lbs raw fish/day	Groundfish - wet line	32,900
	180,000 lbs raw fish/day	Groundfish - wet line	18,500
	40,000 lbs raw fish/day	Groundfish - wet line	10,000

Table 15. Summary of Total Effluent Results from Salmon Processing

Study	Processing and Plant Capacity	BOD_5	S.S.	Ether Soluble Oil
		(Lbs of parameter/1000 lbs of raw fish)		
Study 2	Spring Salmon (Glazing)	1.83	1.2	0.2
	Hand Processing (Canning)	29.1	16.8	3.8
	30,000 lbs. raw fish per day			
	Iron Chink	27.3	22.6	7.4
	70,000 lbs. raw fish per day			
	Salmon Unloading (Hydraulic pumping)			
	Pink	2.8	0.81	
	Sockeye	1.54	0.49	
	Coho	1.13	0.26	

method of unloading salmon. Table 15 indicates that the wastes from the unloading operations vary somewhat but should be considered as part of the plants effluent and should, therefore, be treated in the plants effluent treatment systems.

4.1.2.2 Herring:

There has recently been a marked increase in the volume of herring being processed for human consumption because of the general decline in the total herring catch and restrictions on the use of herring for fish meal.

The major waste sources associated with the variety of herring processing techniques include pumpout water, brine used in roe recovery processing, acetic acid-brine dumps used in the marinating process, and water used during the filleting processes. The majority of wastes are screened prior to discharge, however pumpwater used in the unloading process is usually discharged direct to the harbour.

Table 16 gives the effluent characteristics for food herring production as reported from studies 3 and 5. The total plant effluent from marinated herring does not include the acetic acid-brine dumps. The results shown indicate the high strength of the effluents generated by food herring production. The high BOD_5 and suspended solids in the pumpout water indicates clearly the necessity of treating these wastes in the plants effluent treatment system rather than allowing direct discharge to the harbour.

4.1.3 Shellfish:

4.1.3.1 Lobsters:

Lobsters are processed solely in the Atlantic region. The main waste source occurs from the butchering operations with its associated wash water. The effluent loadings vary from 20 to 30 pounds of BOD_5 per 1000 pounds of raw product with a suspended solids loading of from 4 to 7 pounds per 1000 pounds of raw product. Water usage averages about 2500 Imp. Gallons per 1000 pounds of raw product.

4.1.3.2 Crab:

Crab are processed on both the Atlantic and Pacific coasts, the largest volume being on the Pacific coast. As in lobster processing, the largest waste loads originate in the butchering area. BOD_5 effluent loadings vary from 20 to 60 pounds per 1000 pounds of raw product, with a suspended solids effluent load of between 10 and 30 pounds per 1000 pounds of raw product. Water consumption averages about 6,500 Imp. gallons per 1000 pounds of raw product.

The data given for both the lobster and crab effluent loadings was obtained from study #3.

Table 16. Effluent Characteristics from Food Herring Processing

Study No.	Processing	BOD_5		S.S.		Ether Soluble Oil	
		Conc. (mg/l) Range ($\bar{x}$)	Lbs/1000 lbs raw fish Range ($\bar{x}$)	Conc. (mg/l) Range ($\bar{x}$)	Lbs/1000 lbs raw fish Range ($\bar{x}$)	Conc. (mg/l) Range ($\bar{x}$)	Lbs/1000 lbs raw fish Range ($\bar{x}$)
3	Herring Filleting Total Plant Effluent	3200-5800 (3859)	-- (22)	1150-5310 (3011)	-- (21)	200-3000 (1200)	-- (10)
	Marinated Herring Total Plant Effluent	6900-14,000 (8880)	-- (215)	1508-4600 (3410)	-- (85)	800-5000 (2500)	-- (83)
	Pumpout Water (Herring Pumps)	-- (33,500)	-- (--)	-- (7955)	-- (--)	-- (500)	-- (--)

		COD (mg/l)	Total Solids (mg/l)	Setteable Solids (mg/l)	Soluble Solids (mg/l)
5	Total Plant Effluent	6258	6986	1476	5530

($\bar{x}$)=mean

4.1.4 Freshwater Fish Processing:

There is in Canada a sizeable freshwater fish processing industry. Study #1 was carried out at a plant which processes approximately 30 million pounds of perch and smelt per year. This plant fillets perch whereas smelts are eviserated. The combined effluent loadings from this plant are given in table 17. The sampling of the individual perch and smelt effluents as well as the combined effluent indicated the dampening effect of mixing the two component flows as the combined effluent is stronger, but less variable on a day to day basis, than its individual component parts.

During the study, water use in the plant was examined and found to be relatively constant at about 295,000 Imp. gallons per day, irrespective of the volume of fish processed. This is shown diagramatically on figure 5. A number of other studies also indicated that the rate of water usage was relatively constant regardless of the quantity of fish being processed.

Table 17. Combined Perch and Smelt Wastewater Characteristics (Study#1)

	BOD_5		S.S.	
	Conc. (mg/1)	Lbs/1000 lbs raw fish	Conc. (mg/1)	Lbs/1000 lbs raw fish
Mean	3044	4.5	1397	2.3
Standard Deviation	±1413	±2.0	±724	±1.3
Coefficient of Variation	46.3%	45.4%	51.8%	58.7%
Number of Samples	40	29	40	29

4.1.5 Fish Meal Production:

The processing of fish meal can lead to the discharge of high strength wastes. A review of table 18 indicates the advisability of limiting the direct discharge of bloodwater and stickwater to receiving waters. Many plants do in fact recover both their bloodwater and stickwater, producing fish meal, condensed solubles and oil from these waste products. Such recovery practices should be encouraged in those plants which presently discharge their waste direct to the receiving water.

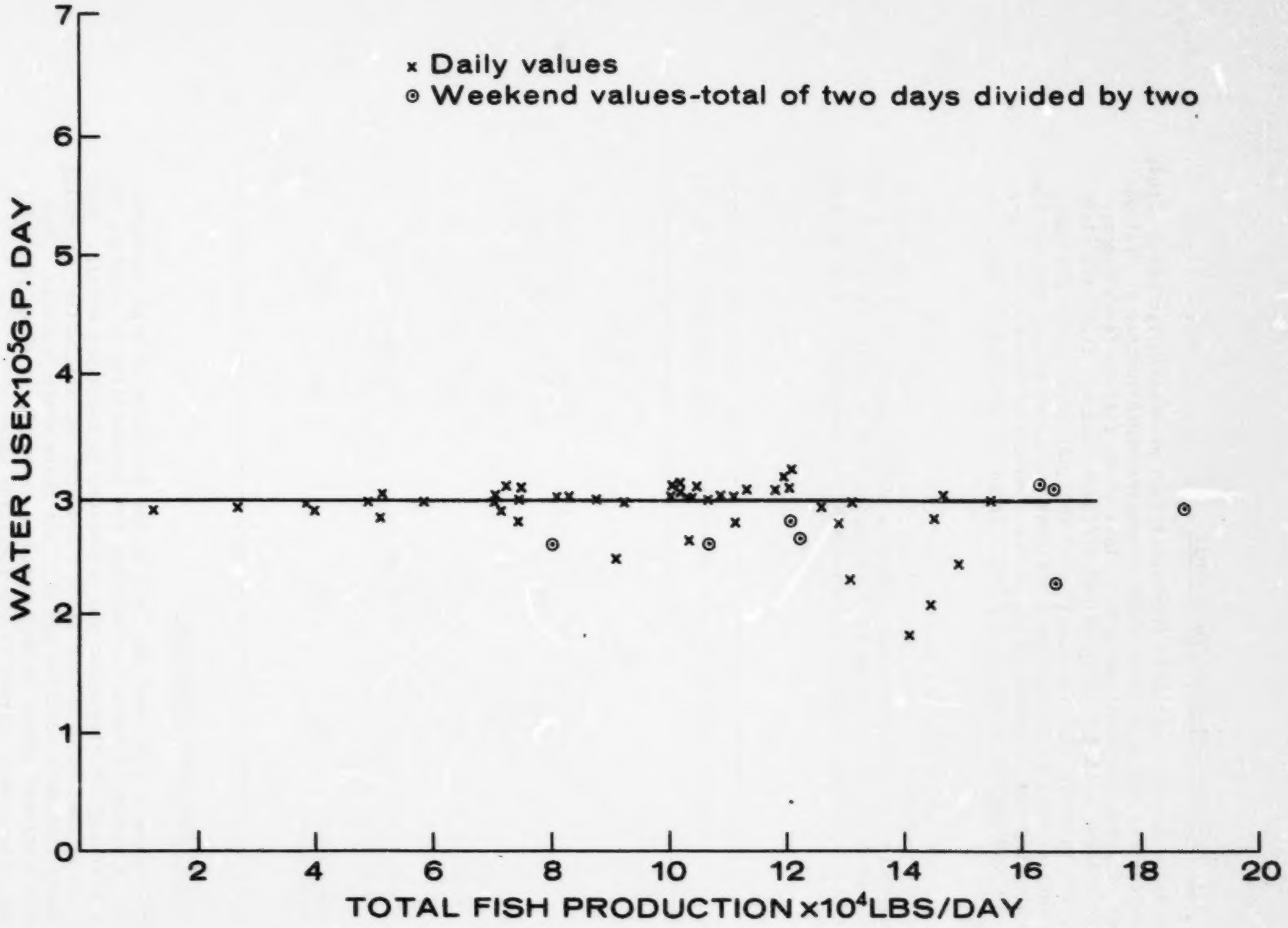

Figure 5. Water Use Against Total Fish Processed Per Day

Table 18. Average Effluent Characteristics from Fishmeal Processing

Waste Stream	BOD_5 (mg/l)	SS (mg/l)	Ether Soluble Oil (mg/l)
Non-Oily Bloodwater	120,000	--	3,000
Oily Bloodwater	80,000	15,000	--
Deodorizer Water	20	100	--
Condenser Water	10	80	--
Stickwater			
Groundfish	120,000	10,000	300
Herring	70,000	30,000	5,000
Perch and Smelt	160,000	66,000	1,200
Pumpout Water	34,000	8,000	500

Many of the studies reported previously indicate that the results obtained from BOD_5, suspended solids and oil analyses varied widely. This is due to:

1. Inherent sampling and analysis problems.
2. Variable characteristics of the fish such as age, sex, and season of the year.
3. Variations in the catch handling and storage techniques employed by the fishermen as well as the time required to transport the fish to the plant.
4. Variations of off-loading, storage and processing techniques employed by the plants.

Reliable results from fish plant effluents studies can only be obtained from a thorough sampling program. In most cases such a sampling program can only be carried out on the total effluent.

4.2 Treatability Studies:

4.2.1 Physical Treatment:

4.2.1.1 Screening:

In the course of pilot plant studies on the treatment of fish processing wastes, the Vancouver Laboratory of the Fisheries Research Board of Canada (Study #5) established that tangential screens equivalent to 40 mesh screens could successfully screen salmon canning wastewater and herring pumpout water. A diagram of such a screen is shown in figure 6. A design flow-rate of 50 IGPM per foot of cross-section could be maintained with periodic high pressure spraying of the screen surface to prevent clogging.

In a subsequent demonstration unit designed by the Fisheries Research Board staff, two 6 foot 45 degree tangential screens were used in parallel to handle a flow of 650 IGPM of salmon canning wastewater. The screen sizes were equivalent to 18 and 25 mesh respectively and subsequent visual examination revealed that the 25 mesh screen was subject to less plugging. With the addition of high pressure sprays working on a time clock of 10 seconds on every three minutes, the screens have operated satisfactorily and effectively on water from salmon canning, groundfish filleting, salmon unloading, herring unloading and herring roe recovery. These screens are preceded in line by a 4 mesh rotary screen, and typical recovery rates are given in table 19.

Table 19. Solids Removal by Tangential Screens (Study #5)

Wastewater Source	Flow Rate (Gals/ft. of cross section)	Insoluble Solids Removal %	Dry Solids Recovery (lb/hour)
Salmon Canning	56	43	280
Groundfish	66	10	24
Herring pump water plus process water	28	50	1500

During study #1 the effect on smelt and perch processing effluents of 20 mesh tangential screens, similar to that shown on figure 6, was examined. The percent suspended solids removals are shown in table 20.

Further tests of 25 mesh tangential screens are to be carried out on groundfish filleting effluents and pumpout water. These tests should be complete by August 1973.

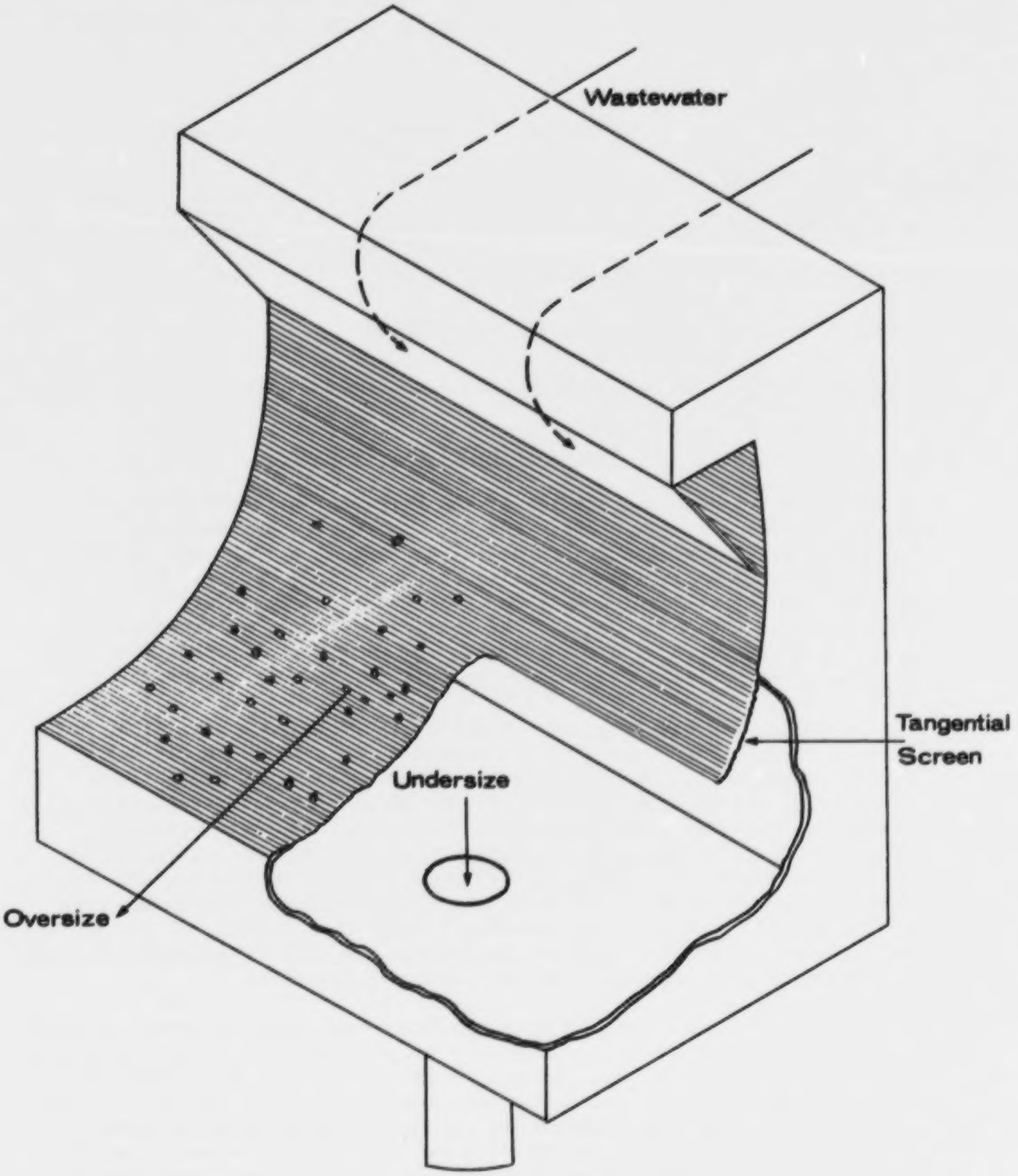
Wastewater
Tangential
Screen
Undersize
Oversize

Figure 6. DSM Tangential Screen

Table 20. Suspended Solids Removal by Tangential Screens
(Average and standard deviation of the S.S. Concentrations)

Wastewater Source	Before Screening (mg/l)	After Screening (mg/l)	Percent Removal
Smelt Processing			
Line 1	2362±380	1621±261	31.4
Line 2	3434±483	2473±332	28.0
Perch Processing	1107±191	825±156	25.5

4.2.1.2 Flotation for Protein and Oil Recovery:

Based on the pilot plant studies of the Fisheries Research Board of Canada, a demonstration protein and oil recovery system has been installed at a Steveston fish processing plant as a joint venture of the Fisheries Association of British Columbia, B.C. Packers, Ltd., and the Industrial Development Branch of the Fisheries Service, Department of the Environment. The unit was designed by Fisheries Research Board staff, and the operation of the unit has been monitored for two years. A flow diagram of the unit is shown in figure 7.

The unit consists basically of two 6-foot tangential screens of 18 and 25 mesh respectively, operating in parallel, followed by a dissolved air flotation cell. In this unit the screened water is pressurized to 45 psig, air is injected at 2 percent by volume, and retention time under pressure is supplied to allow the air to enter solution. As the pressure is released by passage through a throttling valve the water enters a baffled tank. The dissolved air is released under the reduced pressure in the form of minute bubbles which attach themselves to the solid or oil particles present. These rise rapidly to the surface and are skimmed off for recovery of protein and oil. The clarified liquid is withdrawn by stand-pipe from the bottom of the tank.

The use of chemical additives has been found necessary for proper clarification, for emulsion breaking, colloid destabilization, protein precipitation and flocculation. Two chemical combinations have been found to be effective for treating wastewater generated in fish processing. The one utilizes a caustic-alum combination and the incoming water is dosed with sodium hydroxide to raise the pH to about 9.2. Enough aluminum sulphate is then added to lower the pH to about 5.4 The other utilizes alum-polymer combination and enough aluminum sulphate is added to lower the pH to about 5.4 and an anionic polyelectrolyte is added to assist the proper flocculation. Both systems are equally effective but the latter has been favored slightly due to lower chemical costs, ease in solids recovery and lesser sensitivity to operating parameters. The clarification achieved

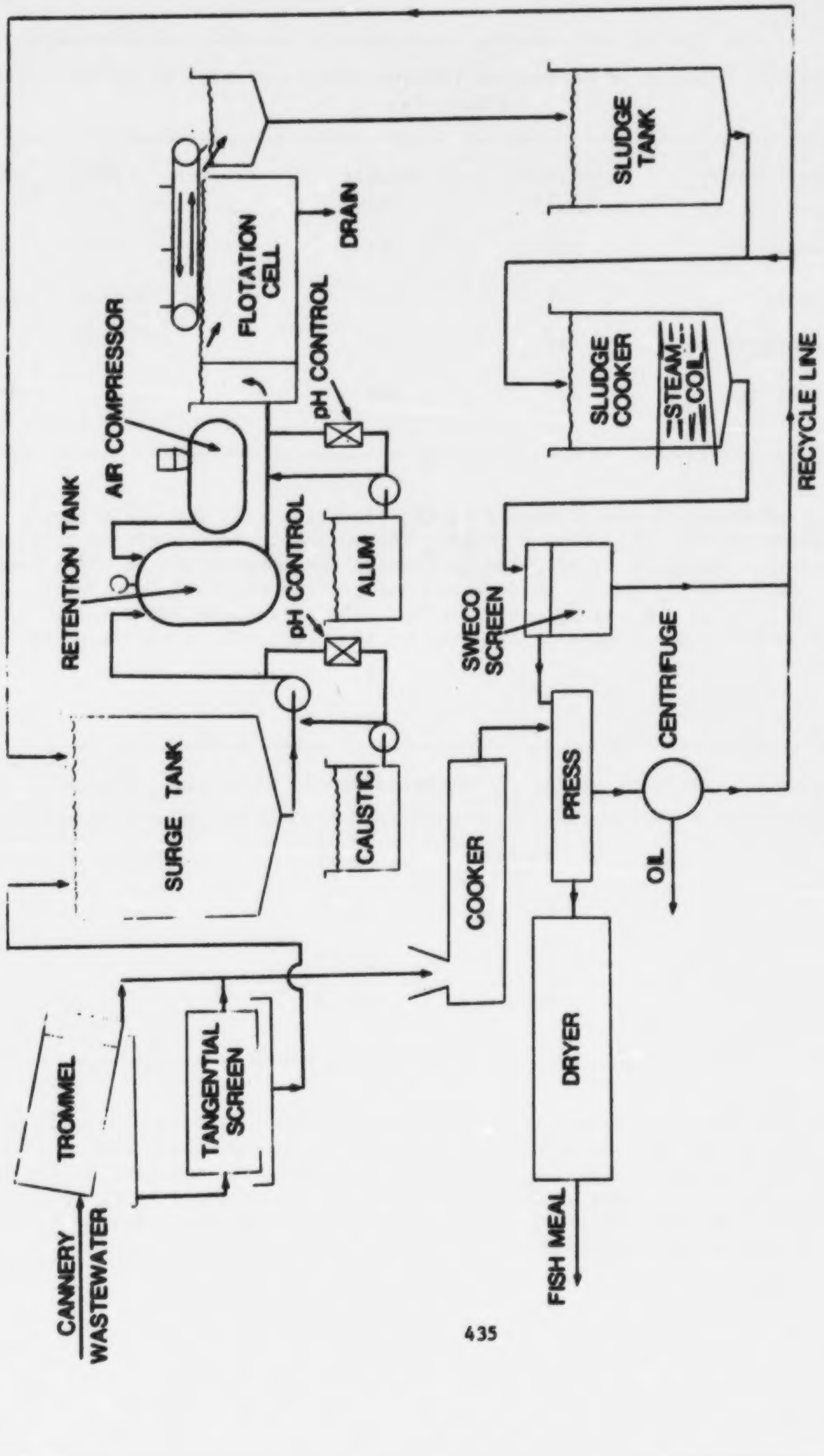
CANNERY WASTEWATER
TROMMEL
TANGENTIAL SCREEN
SURGE TANK
CAUSTIC
RETENTION TANK
pH CONTROL
ALUM
AIR COMPRESSOR
pH CONTROL
FLOTATION CELL
DRAIN
SLUDGE TANK
COOKER
PRESS
SWECO SCREEN
SLUDGE COOKER
STEAM COIL
RECYCLE LINE
CENTRIFUGE
OIL
DRYER
FISH MEAL

Figure 7 PROPOSED PLANT LAYOUT

is shown in table 21.

Table 21. Degree of Removal of Various Characteristics by Air Flotation (Study #5)

Water Source	Insoluble Solids	Soluble Solids	Protein	BOD_5	Oil
Salmon	92%	28%	61%	84%	90%
Herring	74%	44%	--	72%	85%
Groundfish	86%	14%	--	77%	--
Stickwater	95%	60%	--	--	95%

The solids which are skimmed from the flotation cell represent about 3 percent of the total flow treated. The solids content averages about 5 percent. Recovery is affected by raising the temperature of the stream to about 200 degrees F. to denature the protein followed by removal of the solids and oil by centrifuging. The solids are added to the driers for recovery as fishmeal. Analyses of the recovered solids is given in table 22.

Table 22. Analysis of Solids Recovered by Air Flotation (Study #5)

Protein	65.0%
Oil	9.4%
Ash	12.6%
Moisture	10.1%

The effluent from a flotation cell has a biochemical oxygen demand (BOD_5) of 100 to 500 mg/l as opposed to screened wastewater which ranges from 200 to 3500 mg/l. The BOD_5 remaining is essentially soluble, is readily dispersed in the receiving water, and is easily assimilated by bacteria. In addition, this effluent is fully saturated with oxygen due to the use of dissolved air flotation.

Experiments in the demonstration unit indicated that better than 85% of the solids in stickwater can be recovered during air flotation by mixing 9 parts of clarified effluent with 1 part of stickwater prior to treatment (i.e. operating at 90 percent recycle). The resultant BOD_5 is still very high, averaging over 5000 mg/1, but this does offer a partial solution to the problem of handling salty stickwater. Yet to be established is the value of the recovered solids as an animal feed ingredient, and these experiments are planned for the near future.

Other chemical combinations are possible with the dissolved air flotation process. One currently under test in the Scandinavian countries involves the precipitation of protein by pH adjustment using sulphuric acid followed by reaction of the protein with a derivative for lignosulphonic acid, a pulp mill waste product.

The economics of dissolved air flotation treatment have not been fully established, but based on interim results obtained on salmon canning wastewater, the value of the recovered solids sold as fishmeal should offset the direct operating costs but not the capital investment.

4.2.2 Biological Treatment:

Several problems exist in attempting to design biological treatment systems for fish processing plants. Superimposed on the seasonal nature of the industry are discontinuous operating periods within the seasons. For example, many processing plants operate only one or two days a week in all except the busiest part of the fishing period. Such operations make almost any biological treatment system except lagoons impossible to use. This type of discontinuous flow would tend to upset the operation of all but the largest of joint municipal-industrial treatment plants.

Study #1 examined the treatability of combined perch and smelt wastewater using laboratory scale continuous flow biological reactors. By varying the detention time and sludge age in the continuous reactors, it was found that a sludge age in excess of 3 days is required for optimum removal of BOD_5, both filtered and unfiltered. Figure 8 summarizes the results for the continuous reactors, giving mean percent removals with standard deviations for each sludge age tested.

Examination of figure 8 indicate that increasing sludge age above 3 days with or without sludge recycle did not markedly effect the percent removal of filtered or unfiltered BOD_5. The removal of filtered BOD_5 was approximately 80 percent for each sludge age tested, whereas the removal dropped to approximately 45 percent for unfiltered BOD_5. Maximum BOD_5 removals could be achieved by either a short detention time reactor (7.5 hours) with sludge recycle and a 3 day sludge age or a larger detention time reactor (5 days) with no sludge recycle.

The Fisheries Research Board of Canada's Vancouver Laboratory (Study #5) have been experimenting with the use of a rotating biological contactor (RBC) pilot plant as a high rate biological treatment system for reducing the BOD_5 load after air flotation. This system involves passing wastewater through a compartmented trough in which styrofoam discs are slowly rotating. A biological growth develops on the disc and is

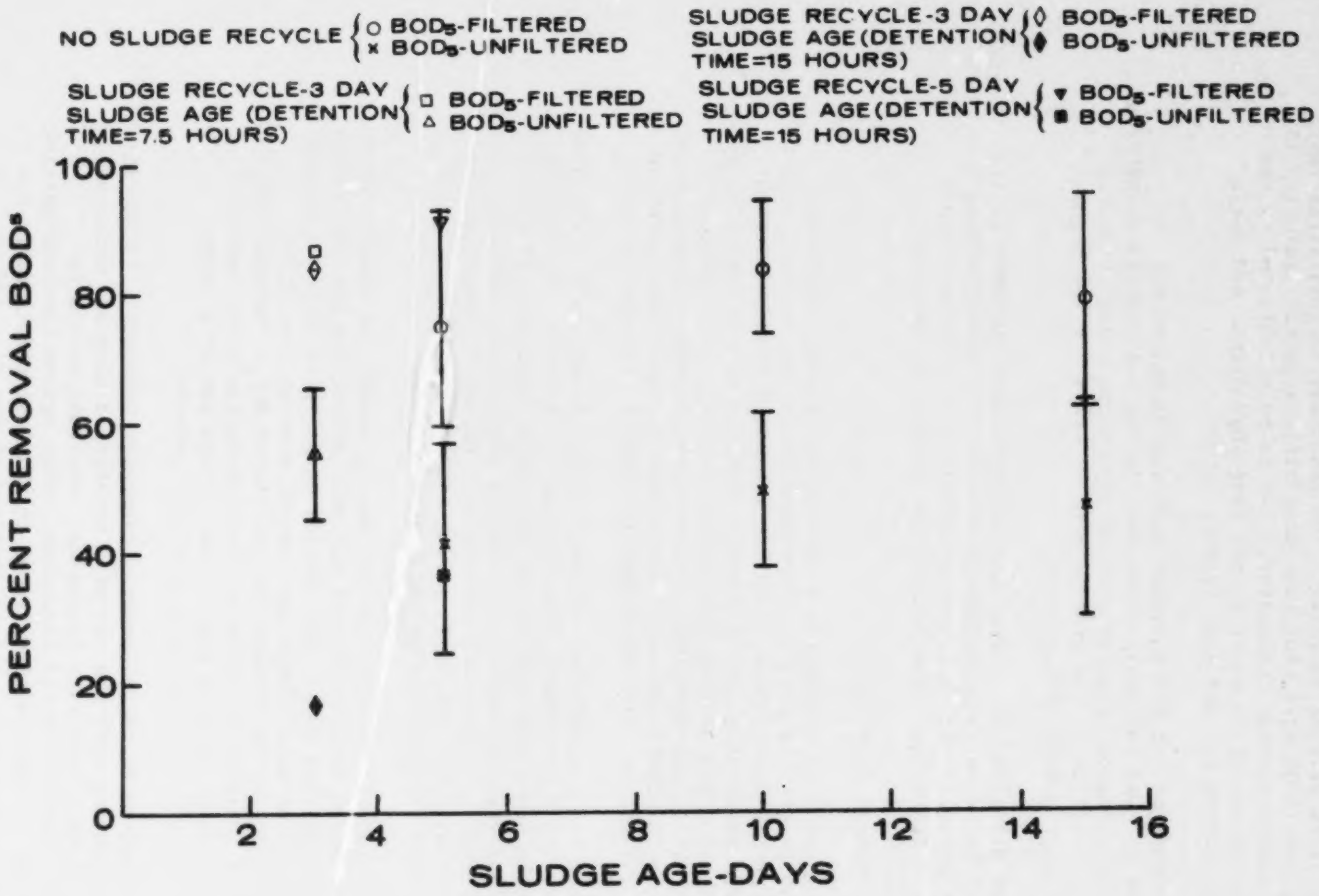

Figure 8. Continuous Reactor Studies-BOD^5
(Combined Wastewater)

alternately exposed to the wastewater and air. Some of the biomass is constantly sloughed off the disc and is carried through the unit to a clarifier. Not only is the system stable to hydraulic surges, but continues to operate effectively under low flow or recycle conditions. Preliminary results indicate that, under normal conditions, a BOD_5 removal of 4.5 pounds per 1000 square feet of disc surface per day is easily attainable on a salmon canning plant effluent previously treated by air flotation, resulting in an effluent of about 50 mg/l of BOD_5.

In addition to previously mentioned advantages, the capital costs of this type of system is competitive with other high rate systems, whereas the operating costs are considerably lower.

4.2.3 Cost of Treatment Systems:

The capital costs associated with the installation of fine screening and air flotation can be estimated fairly readily from the data obtained in the installation of the demonstration unit at Steveston (Study #5). These are in the order of $2,500 and $10,000 per 100 Imp. gallons per minute respectively. Estimation of the cost of biological treatment by aerobic lagoons is more difficult because the largest portion of the total cost is in land aquisition. Roughly one acre of land per 100 Imp. gallons per minute is required if the water is from a groundfish plant or has been previously treated by screening and air flotation to about five acres per 100 Imp. gallons per minute for untreated wastes. Thus near metropolitan areas the cost could range from $40,000 to $200,000 per 100 Imp. gallons per minute to achieve proper secondary treatment, based on a price of $30,000 per acre. A further problem of lagoons would be the availability of suitable land in close proximity to many fish processing plants.

Table 23. Cost Estimate to Achieve Various BOD_5 Levels (100 IGPM of Flow)

Waste	BOD_5 Level (mg/l) 3000	500	100
Salmon	$2500	$12,500	$52,500
Herring	$2500	$12,500	$52,500
Groundfish	--	--	$12,500

SECTION V

CONCLUSION

The five studies undertaken by Environment Canada have provided the fish processing industry with characterization and treatability data on their effluents.

Although there is a good deal of variation in the effluent loadings determined for each type of effluent, characterization results are summarized in table 24.

Table 24. Summary of Characterization Data (Averages)

Fish Processed	BOD_5 Lbs/1000 lbs raw product	Suspended Solids Lbs/1000 lbs raw product
1. Groundfish Filleting		
a) Dry Line	4.5	1.5
b) Wet Line	18.0	15.0
2. Salmon Processing	28.2	19.7
3. Herring		
a) Filleting	22.0	21.0
b) Marinated	215.0	85.0
4. Shellfish		
a) Lobster	25.0	5.5
b) Crab	40.0	20.0
5. Freshwater Fish		
a) Combined Perch and Smelt	4.5	2.3

The major waste streams are associated with the processing of salmon, herring and shellfish. However, all major effluents associated with fish processing are of sufficient strength to require some type of treatment. In the majority of cases the removal of solids is adequate treatment to protect the receiving environment as this will prevent a build up of sludge around the effluent outfall with its consequent effect on dissolved oxygen. Following screening the effluent should be discharged through an outfall which allows sufficient tidal flushing action to dilute the remaining effluent and thus minimize pollution problems.

Bloodwater, stickwater and pumpout water are the effluents of highest strength associated with fishmeal production. Bloodwater and stickwater should be recovered and pumpwater should be fine screened prior to discharge to the receiving environment.

As stated previously fine screening will in most cases provide adequate effluent treatment provided this is coupled with a well designed outfall. In cases where the provision of this level of primary treatment produces an effluent which still creates pollution problems, then either flotation or biological treatment must be considered. In general most fish processing plants do not have easy access to land on which lagoons of adequate size can be built. This problem, coupled with the high cost of less land intensive methods of biological treatment, would lead to the use of flotation as an economical and practical method of secondary treatment. Further, flotation provides some economic return in the form of recovered sludge which can be recycled back to the fishmeal plant.

Acknowledgements

The authors wish to express their thanks to F.G. Claggett, Fisheries Research Board of Canada for his valuable contributions to this paper.

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BIOLOGICAL TREATMENT OF EGG PROCESSING WASTEWATER

by

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INTRODUCTION

Many problems exist in treating and disposing of food processing wastewater. The egg grading and processing industry is an example where basic information is unavailable for designing biological treatment systems for wastewater.

This report is based on a study carried out to establish basic biological oxidation characteristics of egg processing wastewater. The laboratory studies were one part of an overall study undertaken to assist a local company*** which was experiencing wastewater problems.

The plant originally stored their effluent in an anaerobic lagoon, and then followed with spray irrigation onto pasture. After complaints from neighbours of obnoxious odors, the company installed two concrete lined aerobic lagoons with surface aerators. The effluent from the lagoons was spray-irrigated during dry weather, or stored in a third earthern lagoon until spray-irrigation was possible. The system still produced odors periodically and in view of a pending plant expansion, the company found that they needed more basic information before being able to decide on a solution to their problem. Initially information was required on the flow rate and pollution parameters of the raw waste, the capabilities of the lagoons for odor control and BOD reduction during both winter and summer conditions, and the possible land requirements for final effluent disposal.

WASTE SOURCES AND CHARACTERISTICS

The company grades and washes about 325 cases of eggs per day (30 dozen eggs per case), and processes about 600 cases per day producing about 16,000 lbs of liquid egg material.

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The combined operation produces a maximum of 12,000 Imp. gallons of effluent per day, having a BOD_5 of about 6,000 ppm, with a total solids content of about 7,000 ppm. The eggshells are collected separately, augered into a truck and disposed of in a landfill operation. Other characteristics of the wastewater are shown in Table 1.

Table 1. Typical Egg Grading and Processing Wastewater Characteristics

Analysis	Mg/l
BOD_5	6300
COD	9780
T.S.	6950
Kjeldahl-N	537
NH_4 -N	48
NO_3 -N	2
$PO_4^{\equiv}$ -P	144

Three other characteristics of the waste should be noted and are a function of plant procedure. During the cleaning of the eggs a chlorine spray (100 ppm) is used in the processing operation to control Salmonella. This cleaning water is used continuously and is collected with other cleanup water containing disinfectants and discharges into the lagoon for treatment. Also at the end of an 8 hr shift, the egg washer wastewater (pH 10) is dumped (150 gal) and arrives at the lagoon in a slug load.

These procedures tend to produce conditions which could upset any active biological system in the lagoons.

BASIS OF DESIGN

The basic system at Brookside uses two aerated lagoons in series. Lagoon 1 has a four day and lagoon 2 an eight day detention time when treating wastewater at the maximum plant flow rate of 12,000 Imp. gal/day. The two 5 HP surface aerators give complete mixing characteristics with no detectable settling of solids. There is also complete oxygen dispersion throughout the lagoons.

Laboratory Model Design

Data obtained through bench scale systems can be informative but extremely hazardous to use in designing full scale treatment facilities. However, realizing this limitation, a model system was developed to simulate the particular aerated lagoon treatment system at Brookside and which would also give the more basic information required to design other systems.

Two complete model systems were constructed to be run in parallel. The replicated experiments were felt to be required due to the unpredictability of the biological system and would give duplicate results for better interpretation of any possible upsets.

The construction of the two stage aerated basin system was from one-quarter inch plexiglass (Fig. 1). The main body of the model consists of a rectangular volume, with a divider partition with fixed overflow to provide the division between the two stages. The bottom corners were provided with one inch corner deflectors to minimize solids settling in the corner extremities. Five liter and ten liter volumes were fixed by the overflow of the first stage into the second stage and by the final overflow respectively. Air was introduced into each basin by diffuser stones connected to plexiglass pipes and the flow rate controlled by needle valves. Small variable speed laboratory mixers gave complete mixing and dispersal of oxygen in each tank with no solids settling. A lid was placed over the top of each system to minimize odor during start up.

BATCH TREATMENT STUDIES

Batch treatment studies were used to determine basic information on the characteristics and treatability of the wastewater during aerobic stabilization. Two complete batch runs were carried out, yielding four sets of data. The two models were filled with 5 liters of egg processing wastewater on the "A" side (5 liter basin) and aerated for 7 days. Daily analyses was carried out on sample aliquots for BOD_5*, COD** and TOC***.

Dissolved oxygen, pH and temperature were monitored. Dissolved oxygen was controlled within a desirable range by varying air flow rates. Stirring rates were maintained at sufficient rates for complete mixing. Table 2 indicates the operating parameters.

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* BOD_5 - Biochemical Oxygen Demand

** COD - Chemical Oxygen Demand

*** TOC - Total Organic Carbon, difference between total carbon and inorganic carbon as analysed with "Beckman Total Organic Carbon Analyser", Model 915.

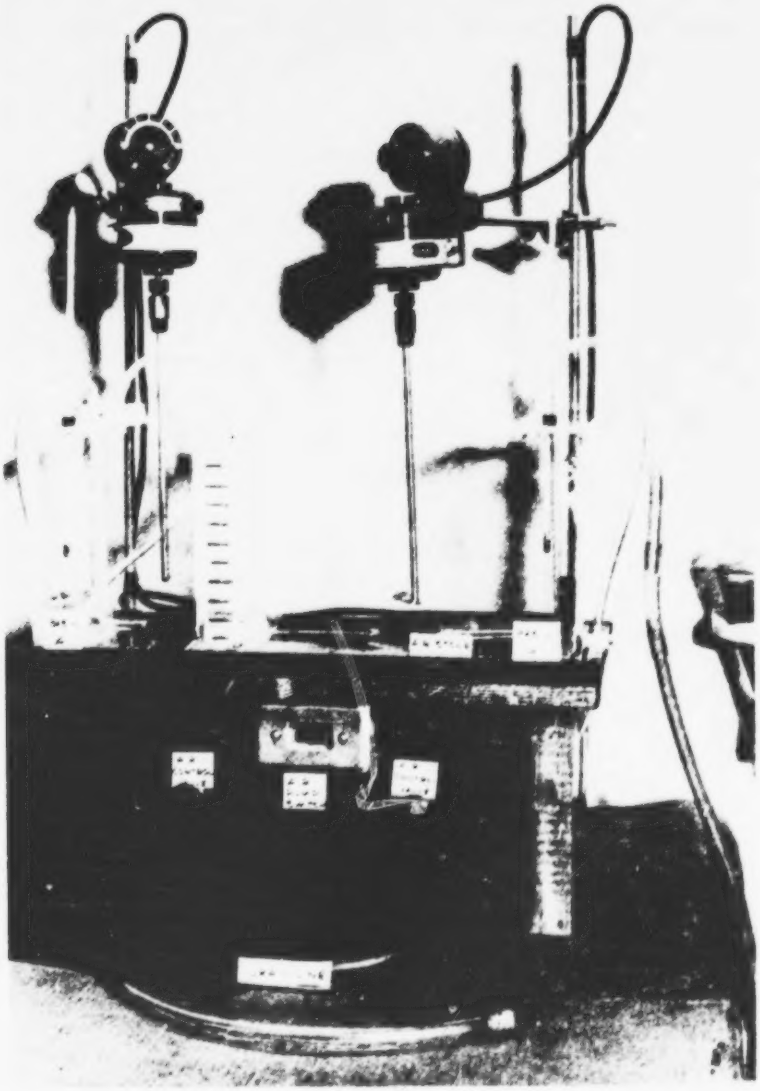

Fig. 1. Laboratory Model of Two Stage Aerobic Treatment System

Table 2. Operating Parameters for Batch Treatment Studies

Operating Parameters	1st Batch Treatment	2nd Batch Treatment
D.O.	2-6 ppm (controlled)	2-6 ppm (controlled)
pH	7.6-8.9 (uncontrolled)	7.2-8.8 (uncontrolled)
Temp.	26°C Model 1	25°C Model 1
	23°C Model 2	25°C Model 2

The pH in the first batch run was initially pH = 8.9 and during the stabilization period, the pH fluctuated between this upper limit and a lower of pH 7.6. In the second batch run, the pH was neutralized at the onset from pH 8.8 to pH 7.5 and fluctuated during the experiment between 7.2 and 8.8. Hence, the pH varied considerably but the system indicated some buffering capacity and remained within a pH range in which there would be minimal cell inhibition.

Results of Batch Studies

In order to facilitate planned research, an attempt was made to correlate the parameters of BOD_5, COD and TOC during aerobic stabilization. It was found that BOD_5 correlated well with COD as indicated in equation [1].

$$BOD_5 = 0.84\ COD - 910 \qquad [1]$$

$$r^2 = .938$$

$$r = \text{correlation coefficient}$$

BOD_5 and COD are mg/ℓ

As expected the BOD_5 to COD ratio was not constant but decreased during the aerobic stabilization as indicated by equation [1].

The correlation between COD and TOC is represented by the following:

$$COD = 3.1\ TOC + 42 \qquad [2]$$

$$r^2 = .987$$

COD and TOC are mg/ℓ

Typical stabilization curves during the batch treatments are shown in Fig. 2. If their decay rate follows the first order rate equation then:

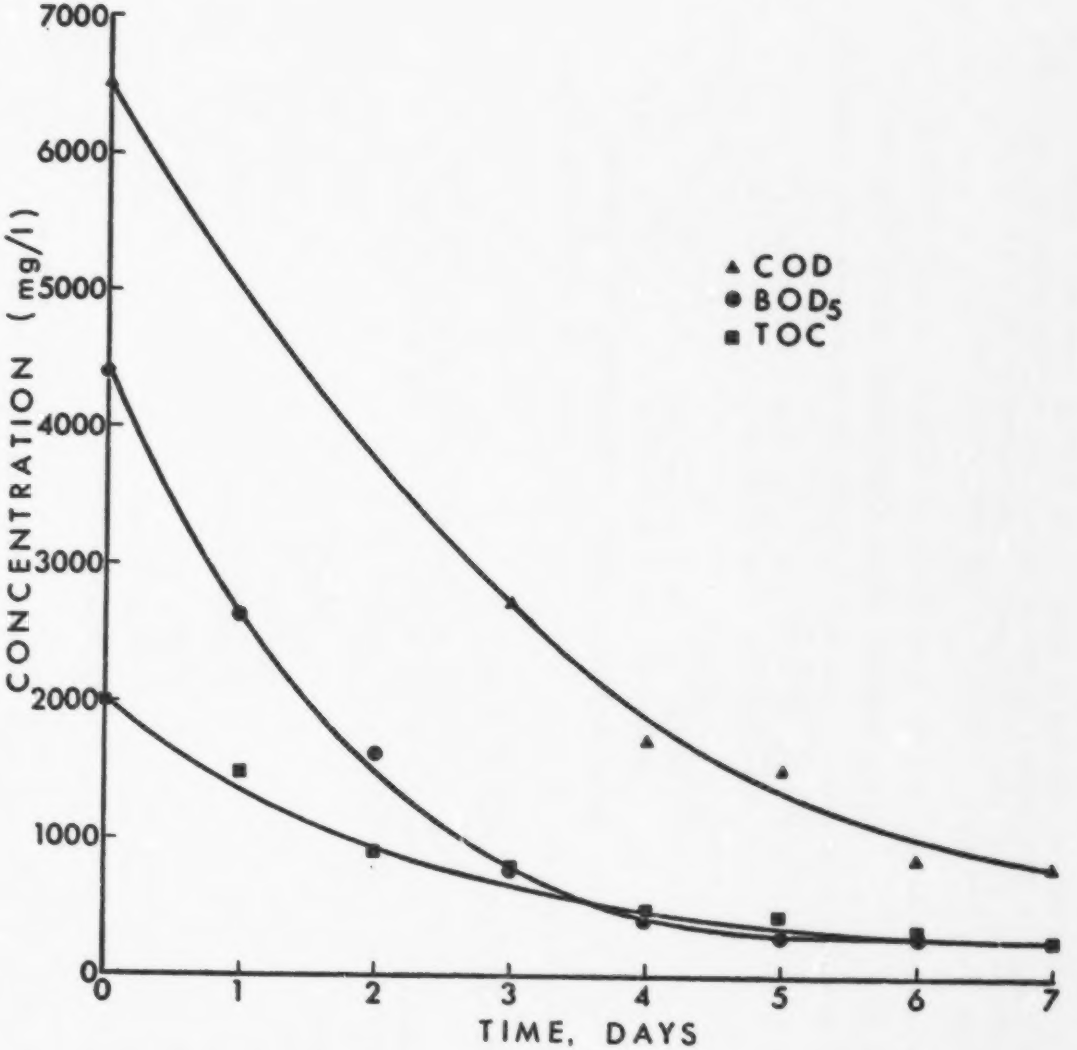

Fig. 2. Egg Processing Wastewater: Batch Treatment Characteristics

$$\frac{dc}{dt} = -k\,c \qquad [3]$$

where c = concentration
k = rate constant
t = time

Rearranging and integrating gives the familiar equation

$$c = c_o\, e^{-kt} \qquad [4]$$

It was found that a semi log plot of $\frac{c_o}{c}$ vs time for the BOD_5 data produced a straight line indicating that the kinetics of the overall treatment process could be represented by a first order rate equation. The rate constants(k) are given in Table 3. The mean removal rate was 0.43/days.

Table 3 BOD_5 Removal Rate Constants Batch Treatment

Batch Test 1		
Model 1	$k = 0.43$/day	26°C
Model 2	$k = 0.36$/day	23°C
Batch Test 2		
Model 1	$k = 0.41$/day	25°C
Model 2	$k = 0.53$/day	25°C

Mean removal rate constant $k_m = 0.43$/day

Qualitative Observations

Color: The color of wastewater undergoing biological oxidation changed considerably during the stabilization period as follows:

Day	Color	BOD_5 (mg/ℓ)
1	greyish white	4,000
2	greyish brown	3,000
3	brown	2,000
4	orange brown	1,500
5	greenish brown	800

It was noted that the color was very indicative and could be qualitatively related to the wastewater strength, in that the analytical results could be predicted very closely by examining color during the batch treatment of this wastewater.

Turbidity

The turbidity of the wastewater decreased considerably during the stabilization period. This is indicative of the solids hydrolysis taking place during stabilization.

Odor

During the initial stabilization, the wastewater exhibited extremely noxious odors even though the system was completely aerobic. This odorous condition decreased during the stabilization period to almost no odor after four or five days. The stabilized wastewater had an "earthy" odor, typical of stabilized aerobic systems. The original odors were most likely a result of organic sulfur groups and proteinaceous materials, resulting in mercaptan and amine odors respectively. Biological growths were evident on the basin walls within 24 hours after aeration and large flocs developed during this initial period. Oxygen transfer into these wall growths and flocs might not be adequate to maintain aerobic conditions leading to anaerobic conditions at their centers which could be responsible for the odors.

CONTINUOUS TREATMENT STUDIES

To determine the treatability of the wastewater under conditions which were more representative of the plant operation continuous treatment studies were carried out at 24°C and 5°C. The processing wastewater was stored in a 5°C cold room and brought into the laboratory as required where it was continually mixed on a magnetic stirrer to prevent solids settling. The model systems were continuously fed from this reservoir using a ministaltic pump. The discharge from the pump was split by a "Y" fitting, and discharged into the 5 ℓ basins (1250 ml/day) above the liquid surface. The flow to each basin was regulated by clamps. This continuously mixed first stage then overflowed into the second stage, basin B, maintaining a four day detention time in basin A. Basin B, kept at a lower liquid level by means of the final overflow, maintained an eight day detention time.

The liquid system was stabilized under constant continuous feeding for at least two weeks after which COD analysis was carried out each day on each basin of each model. When the COD analysis showed little or no change for three successive days, each basin of each model underwent full analysis.

Results of Continuous Treatment Studies

The analysis for the raw waste and for the effluent from each of the two aerobic basins in series after equilibration had been reached are shown in Table 4 for experiments 1 and 2. The results indicate that the waste will undergo a high degree of treatment in these two stage aerobic systems. The

TABLE 4

Analysis	Feed	Basin 1A	Basin 1B	Filtered Basin 1B	Basin 2A	Basin 2B	Filtered Basin 2B
		mg/l			mg/l		
1st Continuous Run							
BOD_5	8,300	4,900	640		5,300	920	
COD	11,000	6,780	2,180		6,300	2,980	
T.S.	7,900	4,140	3,260		4,640	3,380	
Kjeldahl -N	508	438	174		428	202	
NO_3-N	0.45	0.60	27.5		0.50	0.41	
2nd Continuous Run							
BOD_5	7,000	2,700	550	150	2,780	450	100
COD	8,670	3,650	1,580	390	2,940	1,840	320
T.S.	6,280	3,210	2,800		3,100	2,330	
Kjeldahl -N	555	468	162		456	151	
NH_4-N	76	165	17		185	3	
Organic -N	479	303	145		272	148	
NO_3-N	1.75	6.5	188		1.3	148	
PO_4-P	265	90	80		120	150	

percentage reduction in BOD_5, COD, T.S. and Kjeldahl-N in each of the experiments at room temperature and at 5°C is summarized in Tables 5 and 6.

BOD Removal Rate K

The following formula can be derived and has been used to describe BOD removal efficiencies in a completely mixed lagoon which has reached a stabilized equilibrium (1).

$$\frac{Le}{Lo} = \frac{1}{1+K\ t} \qquad [5]$$

or

$$K = \frac{\%\ \text{removal}}{(100 - \%\ \text{removal})\ t} \qquad [6]$$

where Le = effluent BOD
Lo = influent BOD
t = time in days
K = BOD removal rate coefficient.

Using this equation, the BOD removal rate coefficients (uncorrected for temperatures) were calculated for each basin (Table 7).

During run No.1 (Table 5) it can be seen that a very low removal rate in Basin A was experienced in both models. This would indicate that possibly a high pH, due to the caustic in the feed or a high chlorine concentration, were affecting the breakdown rate. This problem appears to have disappeared in basin B resulting in a high degree of treatment. In study 2 a high rate of breakdown occurred in basin A and was followed by an even higher rate in basin B. The lower rate in basin A could again be due to the same problems as in run No.1, or it could be due to hydrolysis and liquification of solids in basin A being followed by breakdown and cell assimilation in basin B.

The overall removal rates for the two basins in series was still quite consistent even though removal rates within each basin of the system varied. The average removal rate for basin B is 0.65/day.

The reduced removal rates at the low temperature were to be expected but even at 5°C, 78% BOD removal was achieved. This gave an average BOD removal rate of 0.2/day.

The temperature effect on the removal rate can be expressed as:

$$K_T = K_{20°C}\ \theta^{(T-20)} \qquad [7]$$

where θ = temperature correction coefficient
T = temperature °C.

TABLE 5 TREATMENT EFFICIENCY FOR CONTINUOUS TREATMENT AT 24°C

RUN NO. 1	PERCENTAGE REDUCTIONS					
	First Stage	Second Stage	Overall	First Stage	Second Stage	Overall
Wastewater Parameter	From Feed to 1A (%)	From 1A to 1B (%)	From Feed to 1B*(%)	From Feed to 2A (%)	From 2A to 2B (%)	From Feed to 2B**(%)
BOD_5 (mg/l)	41	87	92	36	83	89
COD (mg/l)	38	68	80	42	53	73
T.S. (mg/l)	48	21	59	42	27	57
Kjeldahl-N (mg/l)	14	60	66	16	53	60
RUN NO. 2						
BOD_5 (mg/l)	61	80	92	60	84	94
COD (mg/l)	58	57	82	66	37	79
T.S. (mg/l)	49	13	55	50	25	63
Kjeldahl-N (mg/l)	16	65	71	18	67	73

* Model 1 overall, Feed to filtered effluent % BOD reduction = 98%

** Model 2 overall, Feed to filtered effluent % BOD reduction = 99%

TABLE 6 TREATMENT EFFICIENCY FOR CONTINUOUS TREATMENT AT 5°C

Wastewater Parameter	PERCENTAGE REDUCTIONS					
	First Stage	Second Stage	Overall	First Stage	Second Stage	Overall
	From Feed to 1A (%)	From 1A to 1B (%)	From Feed to 1B (%)	From Feed to 2A (%)	From 2A to 2B (%)	From Feed tp 2B (%)
BOD_5 (mg/l)	42	63	79	56	48	77
COD (mg/l)	38	43	65	37	36	60
T.S. (mg/l)	31	22	47	29	22	45
Kjeldahl-N (mg/l)	18	47	57	17	34	46

TABLE 7 BOD REMOVAL RATES FOR CONTINUOUS TREATMENT

	Model 1		Model 2	
	Basin 1A	Basin 1B	Basin 2A	Basin 2B
Study 1 (24°C)	0.17	0.84	0.14	0.61
Study 2 (24°C)	0.39	0.49	0.37	0.65
Study 3 (5°C)	0.18	0.21	0.31	0.11

Using this equation and the removal rates determined at 24°C (K_{24} = 0.65/day) and 5°C (K_5 = 0.2/day) a value for θ was calculated to be 1.07.

Eckenfelder (2) gives the following general values for θ for biological treatment processes:

Process	θ
Aerobic lagoon	1.035
Aerobic-facultative lagoon	1.07-1.08

Hence the calculated value is close to the typical values found for this type of treatment. Since the experiments were carried out at only two temperatures the value of θ is only an approximation but since the temperatures used are at the extremes of the possible temperatures which might be experienced in practice, there should be no sudden unforeseen reduction in θ with lower temperatures. This can occur when θ values are used in designing systems for operation at temperatures lower than those used in the experimental determinations of K.

In basin A COD removal followed BOD removal (Table 5) as was expected but in basin B COD removal was not as great as BOD removal. This reduction in COD removal was also to be expected as the oxidizable materials in the wastewater are being converted to more stable forms which still exert an appreciable COD but a lower BOD.

It is of interest to follow the change in the forms of nitrogen in the basins (Table 4) at room temperature. In the raw waste 86% of the nitrogen is in the organic fraction, with the balance being in the form of NH_4-N. In basin A at equilibrium about 20% of the organic nitrogen had been converted to NH_4-N with a very slight increase in NO_3-N. In the second basin B, both organic and NH_4-N have decreased in concentration being converted to NO_3-N. A mass balance on nitrogen indicates that about 40% of the total nitrogen has been lost from the system presumably given off mainly as NH_3 to the atmosphere.

Qualitative Results for Continuous Treatment

Nutrient requirements: To ensure that adequate nitrogen and phosphorous were available and low concentrations would not be responsible for inhibited growth of cells, the BOD_5 to N and P ratios were calculated for the wastewater. Typical ratios were:

BOD_5 to N	13 to 1
BOD_5 to P	26 to 1

Since ratios of BOD_5 to N of about 32 to 1 and BOD_5 to P of 150 to 1 (3) have been shown to be adequate in most cases, there appears to be an abundance of nutrients in the wastewater to support bacterial growth.

Solids settling: Although neither the time nor the facilities were available for complete coagulation, flocculation and settling studies, some tests were undertaken on model effluent settling.

The plant effluent (model feed) did not show any signs of settling after more than 24 hours. This is probably due to the colloidal nature of the solids system.

The model effluent, however, showed good settling with a clear supernatant and a bottom cell sludge blanket. Additions of aluminum sulphate increased flocculation considerably resulting in higher settling rates. These settling characteristics, together with the filtered effluent BOD_5 data of Table 4, indicate that clarification for the treated effluent could be used as an efficient final stage in the treatment process increasing the BOD_5 removal from 93% to 98% and COD removal from 80% to 96%.

SUMMARY

Two laboratory wastewater treatment models were developed to obtain biological oxidation characteristics of an egg grading and processing plant wastewater discharge into existing aerated storage lagoons. The laboratory models were operated in batch and continuous feed mode at temperatures of 5°C and 24°C.

Qualitative observations indicated that wastewater color was indicative of BOD_5 values changing from greyish white at 4,000 mg/l BOD_5 to greenish brown at 800 mg/l BOD_5. Odors changed from an initial "noxious" to final "earthy" smell after 4 to 5 days. The very poor clarification characteristics of the wastewater were greatly improved by the aerobic treatment and would make clarification of the final effluent practical.

For the two stage continuous aerobic treatment model (4 days and 8 days detention times in series) 93% BOD_5 and 80% COD removals were found at 24°C.

For the batch treatment model the BOD_5 mean removal rate constant k_m was found to be 0.43/day at 25°.

For the continuous treatment model the BOD_5 mean removal rate constant K_m was found to be 0.65/day at 24°C and 0.2/day at 5°C.

A nitrogen balance on the continuous treatment system indicated a 40% loss in total nitrogen during the 12 day treatment at 24°C.

Acknowledgements

The authors wish to acknowledge the cooperation and the financial assistance of Brookside Farms Ltd. in conducting this study.

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EVALUATION OF RESEARCH AND DEVELOPMENT NEEDS FOR THE FOOD PROCESSING INDUSTRY

Franklin J. Agardy, Ph.D. *

Introduction

It might be appropriate to review the background – where we have been. I see the beginning in September 1967 when the Cost of Clean Water Series was published by the Federal Water Quality Administration and suddenly industry, and particularly the food processing industry, became aware of the fact that somebody else was looking at them. It is of value to note some of the information in the 1967 publication, Series No. 3, which addressed the food processing industry. Interestingly, it was projected that by 1972, the waste treatment state-of-the-art would result in removals of 68 percent of BOD in the wastes, 77 percent of the suspended solids and about 19 percent of the total dissolved solids, and it was projected for 1977 that 73 percent of the BOD, 82 percent of the suspended solids, and 25 percent of the total dissolved solids would be removed. That was only some six years ago and now that study reads like a comic book. I happen to have worked on that study and I made other projections as to what I thought would be the situation. My colleagues felt that my numbers were extreme and they were laid to rest.

The next step came about more recently. The now "obsolete" effluent limitation guidelines published through October of 1972 resulted from an industrial waste studies program sponsored by the Environmental Protection Agency. Reviewing the food processing industry, we found that, in addition to information on BOD and suspended solids, which was available in 1967 from the industry, the expanded list included pH and COD, and that accomplishment in a six-year interval is called progress. However, the guidelines also pointed out some other constituents that the food processing industry must be concerned with in the way of characterization. This included color, fecal coliforms, total phosphorous, temperature, TOC

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and, interestingly enough, TDS, which was recorded in 1967 but for which data was missing in 1972. Presently, there is another EPA study underway. By the way, I was involved as a consultant to EPA on the study reported in 1972 and URS Research Company is one of two firms working on the survey being conducted presently. In addition to the parameters included in the publication of 1972, the following parameters are being evaluated: total suspended solids, total solids, total coliforms, phosphate, lead, zinc, mercury, pesticides, PCB's, dissolved oxygen, alkalinity, nitrogen, nitrates, and oil and grease.

So, in the short space of six years, we have moved from no information to a voluminous amount of data that is going to be collected on the industry and, believe me, treatment will have to be accomplished because in rather short order, perhaps in October of this year, there will be limitations on virtually every one of the constituents listed.

There were two other events which, I feel, are historic — two events which, I feel, will have an even more significant impact upon the industry than the 1972 Clean Water Act. The first of these was the 1969 National Environmental Policy Act, a rather innocuous act referred to as NEPA. This act stimulated many states to pass legislation concerning environmental quality and industry will soon discover, if it has not already done so, that not only will new treatment facilities be required to meet effluent requirements but industry will have to see to it that the treatment facilities meet general environmental and ecological constraints placed on the industry by the local communities as well as state and federal governments.

The other action, also a seemingly innocuous act, the 1899 Permit Program, having been resurrected from the dead, lasted about two years and was laid to rest with the passage of the 1972 Water Quality Act. In its brief life, it did establish, rather magnificently, the requirement for industry to monitor their effluents and to report the results. The very fact that information filed under the 1899 Act is still sitting in somebody's office in Washington, and that most industries filed for permits and have not received a response, does not change the situation.

The 1973 Conference

Thus, we have what I call a rather recent history of where the industry has been and where it is going. Now, let us turn our attention to this conference and comment on the proceedings. It is notably appropriate that the keynote speaker was an attorney. Let this sink in. He was a lawyer talking to us, not in terms of pollution control, waste treatment problems, and design parameters, but rather he was talking law and he quoted a very interesting aspect of the 1972 Water Quality Act. He said July 1, 1977, the target date. The date was the significant element of his presentation and I will return to this point later. Essentially, he ran up the flag and went back to 1956 when the federal government became involved in pollution control and he attempted to trace the legislation to date. He presented, I think, rather conclusively that with each piece of legislation, the requirements became tougher and tougher, and while he did not say so directly, he implied that industry tended to sit back and watch and wait and not respond very actively, although the flag was there. To those in the industry who are going to suffer in the next several years, all I can say is that the flag was up but industry was slow to salute. Now the penalty will be double, a fine for failure to salute and a permit fee in order to salute. Industry will have to pay for each "privilege."

Reviewing the technical portion of the conference, we find a number of papers which fell into four basic categories. While I would like to go into each category in detail, reviewing selected content, time really does not permit it. However, I am going to review the substance of each area.

A large number of papers addressed the subject of problem definition and here, I think, is an important element because industry has spent considerable time hassling with problem definitions. Some people assume, and perhaps correctly, that industry is satisfied with this approach on the assumption that what is ill-defined does not have to be resolved.

The second set of papers dealt with in-plant modifications and attempts to reduce water use by industry. This certainly makes economic sense. It was pointed out by several speakers that when we reduce water use, we often get reductions of waste loads.

The third set of papers is perhaps more important because they dealt with by-product recovery and because they did point out, in several cases, practical applications to by-product recovery and included engineering design information necessary to the industry.

The fourth group dealt with treatment processes, and papers included treatment of stillage wastes and land disposal. Also, treatment schemes for distilling wastes, meat packing, starch wastes, and others were developed. Thus, we do have a collection of papers here that gave definitive information ranging from pilot scale to actual field installation studies with some design and, appropriately, cost data.

Conference Highlights

As I see it, there were four speakers whose words highlighted this conference, at least from where I was sitting and viewing the situation as I have to confront it virtually everyday in my role as a consulting engineer and a researcher. The first of these has to do with a slide which Professor Soderquist showed Monday morning. He sort of threw the slide up and casually commented on it, but it was probably the most significant thing in his paper because he showed a relationship between what he called a social optimum cost versus a private sector (industry) optimum cost to arrive at pollution control objectives. The social optimum cost is a constraint posed either by EPA or state agencies and the social optimum cost is, at present, considerably higher than industry had budgeted in its private sector optimum cost. So, somewhere along the line, we are going to have to reconcile these two numbers or go broke. This hypothesis is a significant point which was made casually but nevertheless should not be overlooked.

The second point was made by a rather young, and perhaps somewhat inexperienced speaker, Mr. Hassett, who talked about cost alternatives to industry. He tried to develop a strategy of industry pretreatment versus municipal service charges. Again, I feel this is significant because there are alternatives which are going to have to be explored by industry. However, unless sound definitive information regarding the feasibility of these various alternatives, in terms of cost, is available, solutions will not be readily forthcoming. Here we had a speaker who attempted to develop trade-offs. I do not necessarily agree with the answers he came up with because he appeared to stress pretreatment and, therefore, biased his presentation, but the point was significant. He tried to address economic alternatives and is able to present alternatives to his clients.

The third and most "ideal" solution was presented by Dr. Gallop Monday evening. Unfortunately, the majority of attendees of this conference were not present at his talk because of the late hour. Professor Gallop, of Canada, gave a rather stimulating talk. Really, the first 10 minutes should have been recorded and reproduced for the proceedings. Basically, he said that food processing is really a wastewater business and the commercial product is really a "by-product." The point he made was that we must begin looking at the industry from a total systems concept approach. We cannot continue optimizing production while, and as he so aptly put it, burying the sanitary pipes under the floor where they cannot even be found. We must view an entire plant as a "total system" with the waste element being as important as or, in some cases, more important than the product being put out for commercial sale.

The fourth speaker, whom I would like to single out, was Dick Stephen-Hassard from Hawaii for he, in fact, demonstrated a total systems concept for the sugarcane industry. In this case, on the Island of Hawaii, they are reviewing their industry from the field to the furnace, and he made the point, rather emphatically, that at one of their plants, the primary function is going to be the generation of power and the secondary function, or by-product, is going to be sugar processing. I think this is perhaps the most dramatic illustration of what many of the companies, which make up the food processing industry, are going to have to address themselves to. We must credit this approach a total systems approach. We can no longer develop solutions in terms of a series of bits and pieces connected up, modified and "accommodated." It is simply not going to work. What it will accomplish is to put a lot of companies out of business. I cannot conclude any differently when I see major automotive manufacturers, who represent the most significant contribution to our gross national product, seemingly unable to convince our government, and particularly Mr. Ruckelshaus, of the validity of their point regarding pollution control devices. I do not see the food processing industry exerting any greater leverage. Face the fact that when the requirements for effluent standards are released, industry will have to meet them, and we are not going to be able to meet them piecemeal.

I feel that these four papers dictated a strategy where most other papers were, what I call, tactical, and I will say more on this subject later. I commend those speakers because they were talking about solutions, not problems, but hard definitive solutions.

The Future

What kind of direction do we need? Where do we go from here? Let us review the facts, the status quo, so to speak. It is fact that the 1972 Water Quality Act is law and that there is a definitive time schedule in the law for implementation of effluent standards and treatment requirements. When industry sees the numbers, there will be some cries of anguish. However, there is not going to be very much point in arguing. I believe that EPA has tired of excuses. They have asked, too long, for information that has not been forthcoming from industry.

It is also a fact that user charges are being developed and are going to be with us for a long time. The City of Los Angeles has already sent out 66,000 copies of their regulations to local industry. I am of the opinion that many of those industries discharging to municipalities face a worse problem than those who have been treating their wastes and discharging directly to a receiving water.

It is also a fact that citizens now have the right to sue a "polluting" industry. This is in the 1972 Act, but more significantly, the National Environmental Policy Act and parallel state acts, particularly in California, give the citizen the right to take an industry to court on general environmental and ecological grounds. The people are doing it and they are getting injunctions against industry and they are bringing about temporary closures. This is not the federal government, this is citizen action, and it is not a federal employee with a degree in engineering who is making the decision, it is a judge who is interpreting the law and ruling that the citizen has the right to demand environmental equity.

In an excellent paper given at the AIChE Conference in Southern California last November, Mr. Milton Beychok of Fluor Engineers and Constructors pointed out that for industries planning new facilities, the National Environmental Policy Act or various state environmental quality acts are going to be a much greater deterrent to the development of new facilities than any guidelines promulgated by EPA. He is eminently correct in the position that most industries do not have the foggiest idea of what these environmental acts contain. They usually find out when they are dragged into court, and by then, they are on the losing side.

With these facts behind us, where should this conference go and what do we have to do in the intervening years between now and July 1 of 1977? I stress a "solution orientation" as opposed to "problem definition," because I feel that we can no longer afford the luxury of studying problems; we must develop solutions. I would like to see the next several conferences aimed at the development of a strategy for meeting treatment requirements. To achieve this goal, I see a series of finite objectives to be addressed. The first of these objectives concerns the development of a handbook or guideline for the industry on monitoring. Rather than let each plant manager suffer through the difficulties of developing an extensive monitoring program, we should prepare guidelines for the industry which would indicate the type of tests which will have to be run, the monitoring equipment available, the precise techniques to be used in the analyses, and the typical costs associated with collecting and analyzing data. I would also hope that the question of equipment reliability and data reliability could be addressed. I feel that the people who contribute to this conference do have the capability to put this information together and make it available to the industry. I believe this to be a critical step and something which certainly could be accomplished by next year.

A second objective concerns the consolidation of information which we presently have across the industry on water reuse and reduction. Several speakers have discussed this point. Let us collect the information together and evaluate it. Let the conference have a panel to address this issue. Let us also stress the economics of water reuse and reduction. What will the cost be or possibly the savings gained by reducing water use 20 percent or 30 percent or 40 percent? Let us convert this information to dollars and cents.

Another panel should address the area of unit process modification. Again, a consolidation of all of the information available to this industry based on prior studies and based on information which is forthcoming or translatable from other industries should be consolidated and definitive unit process modifications shown and explained. Let me stress again the need for practical design information coupled with estimates of cost for these systems.

A fourth objective has to do with the subject of by-product recovery. This section should address not only the technology of by-product recovery but also the economics of by-product recovery and sale. It is not sufficient to say that technology allows us to convert a certain type of waste into a by-product. We must also establish whether or not the market for the by-product exists, and if it does exist, is it a regional or national market. We must also determine what the present prices are for this material and whether or not the by-product recovery scheme is competitive with raw materials. Clearly, an engineering solution in terms of by-product recovery is insufficient if the production of x-tons of material suitable, let us say, as a livestock feed supplement cannot be readily utilized because of price competition or because of a shipping constraint. In this example, the only thing which has been contributed by the engineering solution is a solid waste problem which has to be addressed. I submit that we have qualified people in this industry who are capable of putting this information together and who are capable of making a fair and equitable evaluation of the situation.

Several speakers directed their remarks at land disposal as an alternative to treatment and discharge to receiving waters. This is a process which has been used for many years by this industry, but recently a new look at land disposal has emerged particularly as a result of interest shown by the Corps of Engineers and the Environmental Protection Agency. It does appear that in the face of a zero discharge posture, the alternative of land disposal becomes very appealing. However, we must address the engineering of land disposal systems in greater detail. We must also review the significance of the soil mantle as a treatment mode and we must answer the question of how long the soil mantle can accommodate wastes. We must also explore how long it might take before we get a breakthrough of pollutants to the groundwater table. This is particularly relevant because in today's vernacular the Environmental Protection Agency is talking about discharges to streams, navigable waters and marine environment, etc. However, it is clear that the next logical step is going to be reviews of effluent discharges to groundwater systems. So, we must begin looking at land disposal with a greater intensity and recognize this treatment scheme as a very viable treatment alternative.

I have already discussed the implications of a total systems approach within the industry. I really cannot say it any better than Professor Gallop did on Monday evening or show you the potential results any more dramatically than Dick Stephen-Hassard of Hawaii did. The industry must open its eyes to this approach, particularly with regard to the development of new facilities. The present approach of simply adding on elements to existing facilities in the hope that each increment will satisfy the present requirement will ultimately fail to meet 1977 limitations. I would, therefore, like to see a panel address this question of a systems approach and at least delineate the steps involved in reviewing a plant in this concept.

I discussed earlier the significance of pretreatment as opposed to direct discharge to municipal systems. Needless to say, the strict interpretation of the 1972 Water Quality Act will place a certain pretreatment requirement on industry regardless of the capability of the municipality to handle the waste. However, to broaden the subject, I would like to see the alternatives of pretreatment and municipal treatment coupled with the consideration of developing regional treatment facilities which might bring together partially treated waste from a number of industries and municipalities within a given region. This approach is presently being tried in Texas where the Gulf Coast Waste Disposal Authority acts as the centralized waste handling agency for a mix of industries and municipalities. Perhaps some of you are familiar with this operation, but I would like to give some emphasis to it. There are tremendous advantages to this approach if properly employed. California passed a law last June which allows this type of regional agency to be established. The advantage to industry is that the burden for meeting state and federal requirements falls to the regional agency rather than to each individual contributing partner. Further, the state can sell bonds to cover the cost of operating the agency. The industries who are contributory to the centralized facility are partners in the enterprise and essentially guarantee the bond. In turn, industry turns over title of its existing facilities to the new agency and industry is now able to write off the cost as an "operating cost" rather than a "capital cost." It is only necessary to review the tax structure to appreciate the significant gain to industry from this type of approach.

I would further encourage the conference to act as an information center for interpretation of federal and state laws which apply to the industry. I would like to see a panel consisting of process engineers, sanitary engineers, management, regulatory representatives, and environmental lawyers discuss the full spectrum of implications of the various water quality and environmental laws.

I would like to see a paper, at this conference next year or in years hence, address an updated review of the cost alternatives to industry to meet the federal and state requirements. It is significant to note that the 1972 Water Quality Act does require a cost/benefit analysis to be made in order to justify pollution control measures for industry.

Finally, it is obvious that most of the solutions forthcoming to meet federal and state requirements will create large quantities of solid wastes. I feel that this subject must also be addressed in greater detail so that we fully appreciate the implication of an expanded solid waste handling problem.

Summary

Let me return to the subject of strategy. Industry must face the ever increasing demand placed on it by the 1972 Water Quality Act and its implementation deadlines. Industry also needs to respond to environmental quality constraints and industry is beginning to face a serious problem in terms of energy. This all dictates the need to develop a sound strategy with a strong pollution control orientation. Law, engineering, economics and the marketplace must be reviewed in context and strategies developed which will not only allow the industry to survive, but profit, during the "environmental era." We must, therefore, be bold in our approach and move away from the tactical mentality with which we have lived for so long. In this era, decision makers want solutions, not further definitions of the problem. To illustrate this, let us review the implications of the July 1977 deadline for best practicable treatment promulgated by EPA. This is, in fact, a target. Strategies must be developed so that industry is prepared to meet the constraints by the date. On the surface, 1977 is four years away. In reality, 1977 is here. In order to meet a compliance schedule by July 1 of 1977, treatment facilities must be on stream and operating sometime in 1976. This means that construction must begin in 1975, or perhaps even earlier, depending upon the part of the country the particular facility is located in. Assuming six months or so to design a treatment plant, it becomes apparent that the design phase will have to begin in late 1974 or early 1975. What this, of course, leaves us with is less than two years in which to generate the information we need to implement solution strategies.

This conference has been technically stimulating, but it has lacked the overall strategy and direction which is so desperately needed by the industry today. I strongly recommend that next year's conference be reoriented along the lines which I have discussed. Begin with a definition of a strategy or posture for the industry and then develop fundamental, useful information in a comprehensive form which will allow conference attendees to return to their organizations with definitive design information, with a monitoring program, with an understanding of economics, and with an appreciation for the alternatives available, and the result will be the makings of a grand strategy allowing industry to comply with federal and state requirements while continuing to play an active role in our economy and our society.

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